AVIATION STRUCTURAL MECHANIC HANDBOOK

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PREFACE

This Handbook, one of the Navy Training Courses, is written especially for the Aviation Structural Mechanic. This book has been prepared with three specific objectives in view:

1. To provide a ready reference of important charts, tables, and specifications which the AM must use constantly.
2. To furnish a reliable source of information on materials and methods used in structural repair of Naval aircraft.
3. To provide a source that the AM can use in preparing for advancement in rating.

To accomplish these objectives, many definitions, charts, tables and other bits of useful information covering a variety of subjects are included. Chapters 1, 2, and 3 consist of brief definitions of hand tools, machine and power tools, and sheet metal operations—all of which are important to an AM. Chapters 4, 5, and 6 deal with aircraft metals—their properties and treatment. In chapter 7 the various types of aircraft fasteners are described and listed, and their use is discussed. Two chapters, then, are devoted to repair and inspection, and the remaining chapters deal with nonmetallic materials, welding, hydraulics and publications respectively.

In this text, reference is sometimes made to the trade name of an item. These references are made solely to identify the item, and in no way suggest a limitation on its use or procurement. For this use of trade names, grateful acknowledgment is made to the Camloc Fastener Co., New York, N. Y.; Cherry Rivet Co., Los Angeles, Calif.; Dill Manufacturing Co., Cleveland, Ohio; Hi-Shear Rivet Tool Co., Hermosa Beach, Calif.; and the B. F. Goodrich Co., Akron, Ohio.

This NAVY TRAINING COURSE represents the joint endeavor of the Naval Air Technical Training Command and the Training Division of the Bureau of Naval Personnel.

READING LIST

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For Aviation Structural Mechanics

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Aviation Supply, NavPers 10394–A
Blueprint Reading, NavPers 10077
Hand Tools, NavPers 10306–A
Aviation Electrician's Mate, Vol. 1, NavPers 10319

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AVIATION STRUCTURAL MECHANIC HANDBOOK

CHAPTER 1

STRUCTURAL MAINTENANCE HAND TOOLS AND BENCH EQUIPMENT

SHEET METAL BLACKJACK

A long, thin, heavy leather bag filled with small lead shot used as a hammer to rough-shape sheet metal into a die. Use of this device avoids the danger of local bumps which might occur if a hammer or mallet were used.

BUCKING BAR

A smooth steel bar made up in a variety of special shapes and sizes. This tool is used to form a head on the shank of a rivet while it is being hammered. The edges should be slightly rounded to prevent marring the material. Six pounds is the average weight of a bucking bar.

BURNISHER

A hand tool having blades of hardened and polished steel for finishing metals by friction. The tool is either held against revolving work or scraped rapidly over the surface. It produces a smooth surface by compressing the outer layer of the metal.

BURRING TOOL

Any tool used to remove burrs. A countersink, a scraper, and the side of a long small drill are used to remove burrs from small holes. Scrapes, files, grinders, and edge-beveling tools may be used for removing burrs from large holes or outside edges.

Figure 1.—Typical burring tool.

CALIPER

A device used to measure inside or outside dimensions. Although there are several forms, these devices can be grouped into two general types—those consisting of two legs hinged together at one end, and those which consist of a flat bar with two jaws at right angles to the bar. One jaw is fixed; the other slides back and forth on the bar and can be clamped at any point before a reading is taken.

The following paragraphs describe special types of calipers.

HERMAPHRODITE CALIPER.—A caliper having one straight pointed leg and one leg curved (hooked) in slightly. It is used to locate the center of cylindrical work and to lay off or scribe given distances from the edge of a piece.

INSIDE CALIPER.—A caliper used to measure the inside diameter of holes. In order to provide a contact point without interference, the tips of the legs are curved out slightly.

ODD-LEG CALIPER.—A caliper having both curved legs pointing in the same direction. It is used to measure shoulder distances on flat work, boxes, etc.

OUTSIDE CALIPER.—A caliper consisting of two curved legs hinged at one end. In order to provide a contact point

free of interference, the tips hook or curve inward. It is used to measure the thickness of work, such as the diameter of cylinders.

SLIDE CALIPER.—A beam caliper made with a graduated slide.

SPRING CALIPER.—An inside or outside caliper whose legs are under pressure of a C-shaped spring, tending to force them apart. This pressure is counteracted by a nut-and-bolt arrangement so that the position of the legs is varied by screwing or unscrewing the nut.

SQUARE-MICROMETER (VERNIER) CALIPER.—A beam caliper having jaws at right angles to the blade, and having a Vernier-micrometer adjustment which reads to thousandths of an inch. One side of the beam may be graduated to give inside readings, while the other side gives outside readings. It is often called a Vernier caliper.

C-CLAMP

A commonly used simple clamping device. It consists of a C-shaped frame with a flat surface or anvil on one end and a thumb screw through the opposite end.

CHISELS

Any one of a variety of small, hand, cutting tools, generally wedge-shaped. The leading edge of the wedge is sharpened and hardened to provide an effective cutting edge.

CAPE CHISEL.—A chisel with a narrow blade.

COLD (CHIPPING) CHISEL.—Any all-steel, plain, flat chisel used for cutting or chipping cold metal.

DIAMOND (LOZENGE) CHISEL.—Essentially a cape chisel ground with a square end and cutting edge at one corner. It is used for cutting a sharp-bottomed groove.

ROUND CHISEL.—A round-end chisel with the cutting edge ground back at an angle. It is used for cutting oil grooves and for similar work.

DIVIDER

A hand tool consisting of two steel legs rounded and drawn to a fine point and hinged at the head on a hardened steel

cylinder, or stud. A C-shaped spring is placed above the stud in order to force the points of the legs apart. Dividers are used for measuring between points by reference to a ruler, for transferring or laying out distances, and for scribing arcs and circles.

DRAW SET

A rivet set containing a hole slightly larger in diameter and longer than the protruding shank of the size rivet for which it is intended.

DRAWING TOOL.—Any small hand tool used as a draw set. Dollies and bucking bars often have holes drilled in them so that they can also be used as drawing tools.

DRILLS

TWIST DRILLS are of two different types—carbon or high-speed—depending upon the steel from which they are made. Carbon *steel drills*, the least expensive, are commonly used for general shop work. However, many drilling operations demand a high-speed drill that will continue cutting after it becomes red hot.

DRILL SIZES.—There are three common methods of sizing drills—number, letter, or fraction. *Number drills* are sized by number from #80 (0.0135-inch) to # 1(0.228-inch). *Letter drills* are sized by letter from "A" (0.234-inch) to "Z" (0.413-inch). *Fractional size drills* range from $\frac{1}{64}$-inch to 1 inch and larger in diameter.

FILE

To file is to remove nicks, burrs, and sharp edges from all types of metal by rubbing or stroking with a file. *Rough filing* is the removing of high spots or bumps from metal parts to even up the surfaces or contours. *Finish filing* is the removing of small quantities of metal from finished surfaces or contours. There are numerous types, shapes, and grades of files made to be used on various types of metal and for various types of work.

GAGE

Any suitably shaped standard tool that has been accurately finished to some standard dimension for use in checking or measuring the finished dimension of parts, or in accurately measuring distances between parts.

A *master* gage is one whose gaging dimensions correspond as exactly as possible to those of the part. An *inspection* gage is one used by the manufacturer or purchaser in checking the final acceptability of a product. A *working* gage is one used by the manufacturer to check the work as it is produced.

CENTER GAGE.—A flat, thin strip of metal pointed at one end and notched at the other so that it looks like a rather long arrowhead. The angle of the pointed end, and of the notch, or V, at the opposite end, is 60°. Two smaller 60° notches are cut in the side of the gage. Each edge of the gage, on both front and back, is marked off into parts of an inch or meter. These are more commonly fractions of an inch, and the divisions run 14, 20, 24, and 32 graduations to the inch.

DEPTH GAGE.—A tool used in measuring the depth of holes or recesses. The body, or cross-piece, is placed across the hole while the rule, or rod, is slipped into the hole to be measured.

DRILL GAGE.—A flat steel plate with holes of various sizes, each marked with the correct size or number, into which small twist drills may be fitted to determine the sizes of their diameters.

FEELER (THICKNESS) GAGE.—A gage consisting of a number of very thin blades, each of which is accurately ground to a specific thickness. The thickness of each blade is marked on the blade, usually in thousandths of an inch. Any two or more blades may be used in combination to measure the width of spaces between surfaces. It is called a feeler gage because the accuracy with which it is used depends largely upon a skilled sense of touch or feel.

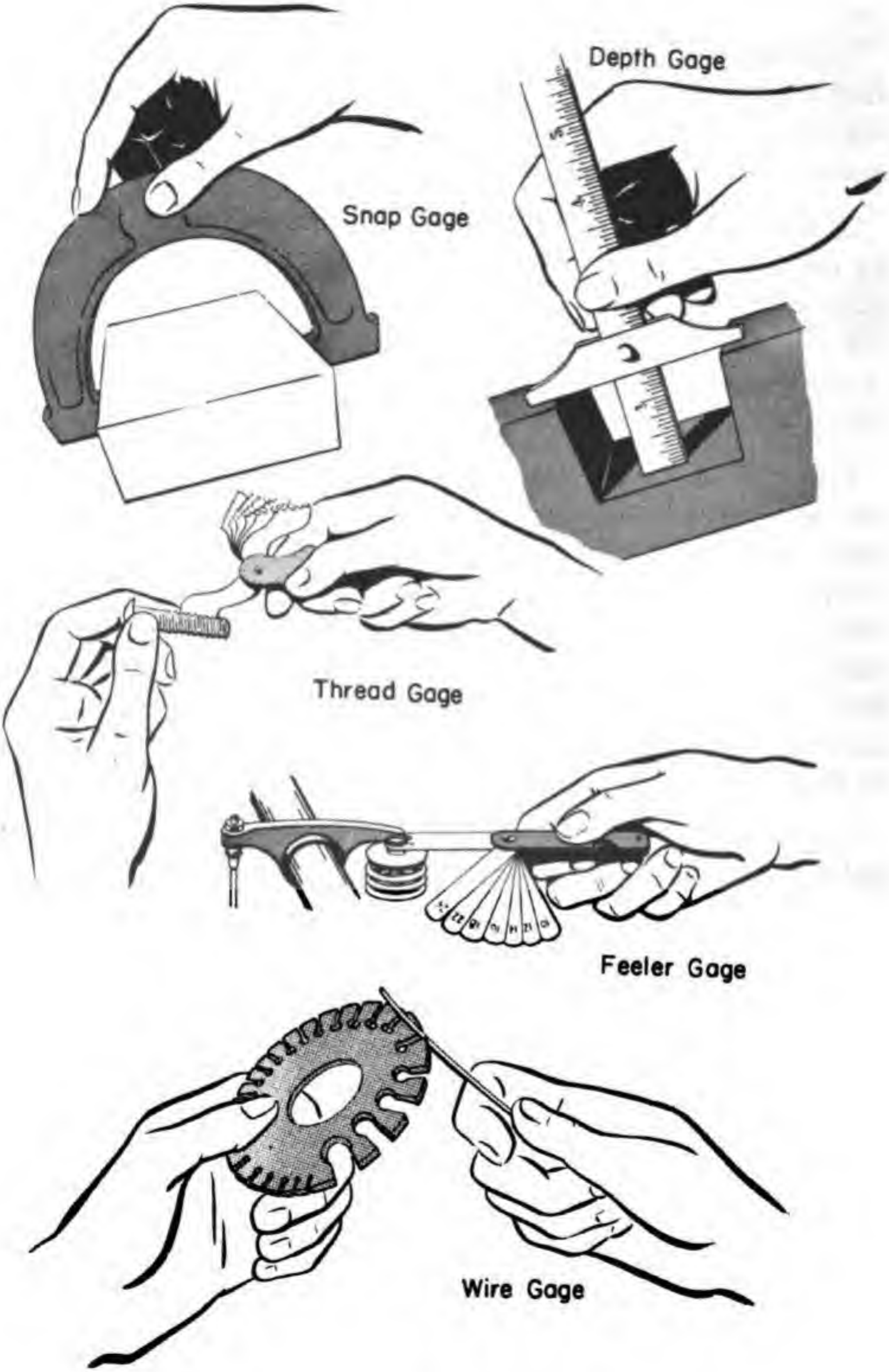


Figure 2.—Gages.

HAND GROOVER

A bar of metal or wood having a groove across one end. It is used to crease and countersink seams in sheet metal so that one surface is flush, or in line, with the other. The folded edges of the seams are hooked together and placed over an anvil or stake. Then the groover is fitted over the seam and struck with a hammer. This raises the seam into the groover and makes one surface flush with the other surface. This process is repeated throughout the entire length of the seam.

HAND HAMMERS

There are three types of hammers—*ball-peen*, *bumping*, and *cross-peen*, commonly used in sheet-metal work.

BALL-PEEN HAMMER.—A hammer with a hard metal head, one end of which has a ball-shaped face for peening, riveting, and truing work; the other end has a cylindrical, slightly convex-shaped face.

BUMPING HAMMER.—A round-faced mallet made of hard wood, plastic or rubber. A hammer similar to the planishing hammer is sometimes used for bumping when the curve is not too great. Planishing hammers are ordinarily used to surface or to smooth off irregularities, following the original shaping or raising operation, or embossing, done usually by other hammers.

CROSS-PEEN HAMMER.—A hammer in which one end of the steel head is wedge-shaped, the blunted point of the wedge being at right angles to the handle. The other end of the head is a cylinder, with a slightly convex face. This hammer is used for swaging, or for drawing out metal in line with the hammer handle.

MALLET

A soft hammer with a relatively short handle and a comparatively large cylindrical head. There are three types—*plain* or flat-faced; *stretching*, with ball-shaped faces; and *shrinking*, a straight or cross-peen type.

MICROMETER (MIKE)

Any one of a number of instruments used to make very accurate measurements of relatively small parts or distances. The principal types of micrometers are the *outside* micrometer (or micrometer caliber), the *inside* micrometer, and the *depth* micrometer. In addition, there are a number of special-purpose micrometers such as the *thread* micrometer, and micrometers for measuring the thickness of metal sheets, or the thickness of walls of tubes.

The basic parts of the micrometer are the threaded spindle, the sleeve or barrel, and the thimble. The thimble makes one complete turn for every marking on the barrel. The circumference of the thimble itself, at the point where it touches the barrel, is marked off into 25 divisions. Thus, by turning the thimble through one division of the 25, the spindle (which is fastened to it) moves one-thousandth of an inch ($\frac{1}{25}$ of $\frac{1}{40}$). If a Vernier is attached, a measurement as fine as $\frac{1}{10000}$ inch can be made.

PUNCH

A tool, usually a short rod of hardened steel, either solid or hollow, with the working or shearing end variously shaped according to its purpose. It is forced into, or through, the material to mark, pierce, cut off, or force out a portion having the size and shape of the punch. It may be used as a hand tool, or as the male part of a die set.

Punch of a die.—A male die which is smaller than, and enters completely into, the mating female die, or matrix.

Hollow punch.—A punch in the form of a hollow steel tube which has the same outside diameter as the hole to be cut in the stock. These tools are used for cutting circular holes ranging from a fraction of an inch to several inches in diameter.

Pilot punch.—A small punch which is placed on the face of a larger punch to increase the accuracy of the punching process.

Pin punch.—A long, slender, solid punch in which the shank back of the tip is the same size as the tip for a dis-

tance and then tapers out to the body diameter. It is used to drive out tight-fitting pins and to remove rivets after the heads are drilled off.

SOLID PUNCH.—A solid steel bar used for punching holes in sheet metal. The cutting end has the same diameter as the cut required—usually less than an inch.

STARTING (DRIFT) PUNCH.—A solid punch in which one end tapers gradually to a blunt point so that it can stand heavy shock blows. It is commonly used to start or break loose straight or tapered pins.

TRANSFER (DUPLICATING) PUNCH.—A center punch with a fixed stop which limits the depth of penetration in the work. It is used to mark locations of centers, bend marks, etc.

RIVET GAGE

A narrow, flat, metal strip with a hole in one end which is used to check the size of the upset (formed) rivet head. The hole is the correct size for the rivet head. Usually its diameter is 0.01 inch greater than one and one-half times

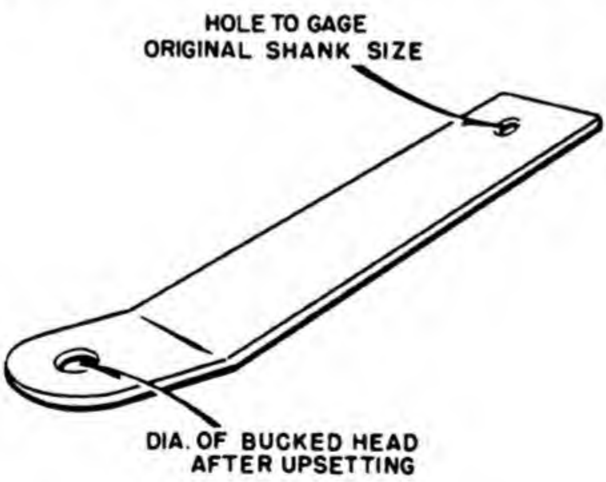


Figure 3.—Rivet gage.

the diameter of the rivet shank. The thickness of the strip, and thus the height of the hole, is equal to one-half of the diameter of the rivet shank. The height of the upset rivet should be between one-half and two-thirds of the diameter of the shank. The diameter of the upset rivet head should

be about one and one-half times the diameter of the rivet shank.

To inspect rivets, the gage is placed over the upset head. If too short a rivet was used, or if it was riveted too much, the head will be below the top of the gage. If too long a rivet was used, or if it was riveted too little, the upset head will project above the top of the gage.

HAND SEAMERS

A type of pliers with very wide jaws, or blades. They are used for bending flanges by hand where a machine cannot be used conveniently.

HAND SET

A punch-like rod or a block of steel having a depression used to back up a rivet when heading it by hand. This hand tool may have one or more small concave (cuplike) recesses, or a hole slightly larger than the rivet shank (a draw set), or both depressions and holes. The hand set may be secured on the work bench or in a vise, the rivet inserted in the work, the head of the rivet pressed against the depression in the set, and the tip of the rivet tapped with a medium-weight ball-peen hammer to form the second head. When the term "hand set" is used in the shop today, the punch-like set is used.

RIVET SET

A small steel tool with one or more saucer-shaped depressions, or with one or more holes, or with both holes and depressions. Each depression is designed to fit one particular size and shape of rivet head. Each hole is slightly larger than the rivet shank on which it is to be used. The hole may be slightly shorter than the portion of the rivet shank that is protruding from the work.

In hand riveting, rivet set commonly applies to the block-like *hand set*, but in machine riveting it commonly refers to a *gun set*.

UNIVERSAL DRAW SET.—A draw set with the hole made in a small ball-like block of metal which is so mounted in the body of the set that it is free to swivel. Thus, the set can often be more firmly seated around the rivet shank than can the ordinary one-piece set.

SANDBAG

A closely-sewed bag filled with fine sand. It is usually made of soft leather or of strong canvas soaked in hot paraffin. Small parts are hand-bumped (hammered) into shape against the sandbag.

SOLDERING COPPER

The solid, pointed block of copper alloy forming the head (tip) of a soldering tool, or iron. It is attached to the handle by means of an iron tank (shank). The copper is heated, usually in a flame, and then used to melt and spread fusible metal on the surfaces to be sealed (soldered). Copper bits are made in four common shapes, and weigh from one to five pounds. They are also called copper bits and coppers.

SNIPS

Any of a group of small, stout, short-lipped hand shears used for cutting sheet metal of 20 gage or lighter. Snips may have any of a variety of blade shapes and either single or compound lever systems. The blades may be straight

Figure 4.—Aviation snips.

(straight snips), curved to the side (curved snips), or curved up. They may be designed for use in either the left hand or the right hand. They may be designed to cut toward the left (left-handed snips) for cutting one side of a hole, or

toward the right (right-handed snips) for cutting the other side.

AVIATION SNIPS.—A special type of snips designed for cutting heat-treated metal stock up to 0.050 inch in thickness. The blades are designed to make sharp turns, and may have fine teeth for cutting aluminum or duraluminum, or coarse teeth for cutting steel.

SQUEEZE RIVETER

A riveting device operated by hand that upsets (forms) rivets by squeezing the tip of the shank toward the original head. This device is essentially a large pair of double-jointed pliers.

In operation, the fixed jaw is placed on the head of the rivet, the movable jaw is placed on the tip of the rivet, and the movable jaw is forced toward the fixed jaw.

Squeeze riveting produces the strongest of riveted joints. The rivet shank is expanded throughout its length and completely fills the hole, making a good bearing surface between the rivet and the material; the rivet is upset (formed) in a single quick operation; rivets are all headed with the same pressure; and all heads are formed alike.

TRY SQUARE

A small hand tool consisting of two steel blades set with the inner edge of one perpendicular to (at right angles to) the inner edge of the other blade. The inner edges can be placed against adjacent surfaces of a work piece to test their squareness—in other words, to see if they form right angles. Try squares are also used to lay off right angles.

AVIATION SHEET METAL BENCH EQUIPMENT

BACK PLATE.—A lead or hardwood block used to support and hold sheet metal stock in place while it is being punched.

BENCH PLATE.—A flat metal plate pierced by tapered rectangular holes to hold stakes firmly and in the correct position.

Bending block.—A flat metal or hardwood block used to bend a flange on the edge of a sheet of metal. The metal is placed on the block with the bend line (the line along which it is to be bent) lying along the edge of the block. This edge must have the desired bending radius. For bending smaller parts, the radius should be the inside dimension of the finished product. The extended edge of the sheet is then hammered around the block with a soft hammer.

Form block.—A wood, metal, or composition block having a form or contour which is to be imparted to sheets of metal, plastics, and the like. Form blocks may be either convex or concave. The stock is placed over the form block and hammered or pressed against it into the desired shape.

Hand form block.—A flat form block whose sides are shaped so that a part can be hand formed on it by blows of a mallet, hammer, blackjack, etc. Such blocks are generally made of wood or lead, but they may be made from masonite, zinc, or steel. The hand form block is used mainly for bending flanges and similar simple forming.

Shrinking block.—A device used for shrinking sheet metal. It consists essentially of two metal blocks. One forms the base; the other is cut away to the contour desired so that the material can be hammered back (shrunk) to fit this contour. A clamp holds the blocks firmly against the material during the process.

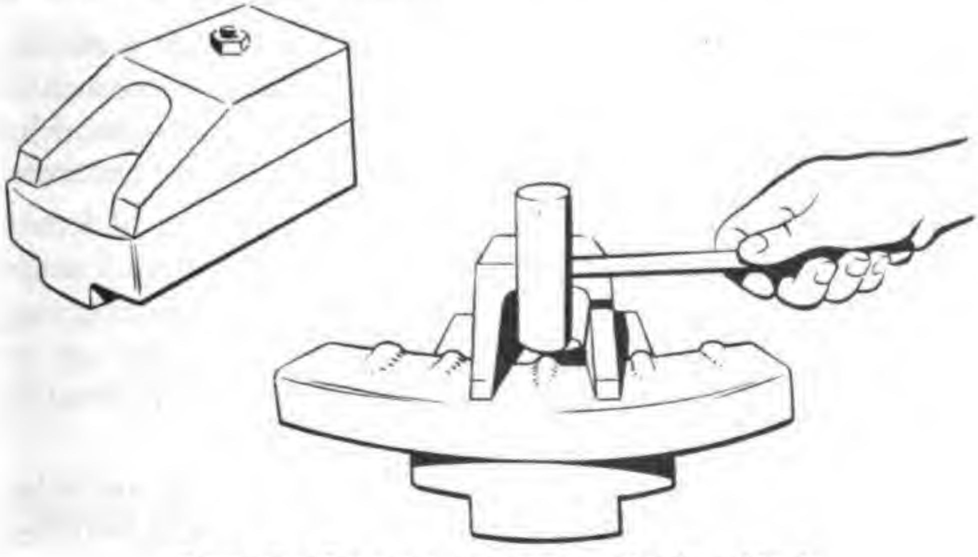


Figure 5.—Removing crimps on a shrinking block.

DOLLY.—A hardened, flat, smooth metal block used to back up blows on sheet metal and on rivets. It is shaped so that it will fit smoothly against the back of the surface being struck.

Variously shaped dollies are used to back up sheet metal against hammer blows, to reshape metal, remove dents, or form seams.

FIRE POT.—A furnace used as a source of heat for soldering or similar operations. The more common kind is a gasoline burner, although charcoal or natural gas may be used.

HOLDDOWN.—An attachment, part, or fixture used to clamp (hold) a workpiece firmly in the desired position while it is being worked on. The holddown presses the work against something else, such as an anvil, bed, or table.

JIG.—Any rigid structure or mechanism which holds parts while they are being fabricated, or while they are being assembled or disassembled. Jigs are used to improve the accuracy and speed of repetitive operations.

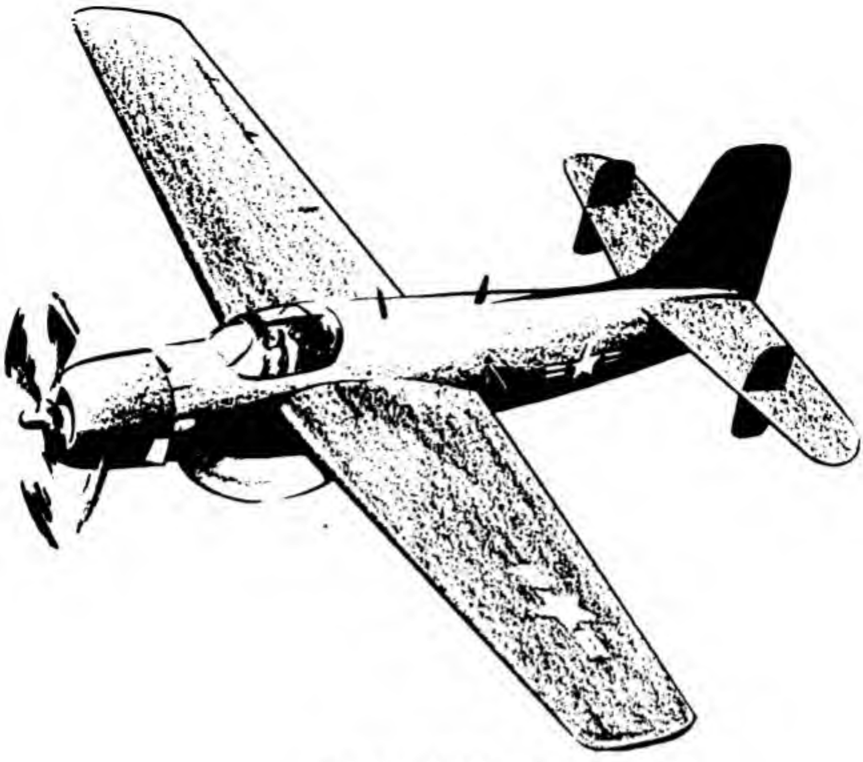
PATTERN.—A piece of metal, wood, or plastic material which is shaped for use as a guide in cutting, forming, shaping, or otherwise fabricating stock into a desired size and shape.

BENCH PRESS.—A small hand-operated brake or press mounted on a workbench, used for bending, shaping, and forming small pieces of sheet metal.

MACHINE STANDARD.—A device used to support a mechanism, hold it in a desired position, or make it more accessible to the operator. It may be designed to support the machine over a workbench or may be attached directly to the floor.

STAKE.—A type of small anvil having a variety of forms. It can be set on a bench plate and used to bend and shape sheet metal to the desired form by hand or by hammering. Its many shapes are very convenient for backing up or supporting otherwise inaccessible portions of intricately shaped pieces.

TEMPLATE.—A pattern made of wood, metal, or other hard material. It is used as a guide in laying out, cutting, shaping, drilling, forming, scribing, or similar operations.



CHAPTER 2

STRUCTURAL MAINTENANCE MACHINES AND POWER EQUIPMENT

BEADING MACHINE

A deep-throated rotary machine which is especially adapted to forming beads (U-shaped grooves) in sheet metal. By attaching the proper pair of roll dies (beading rolls), a single bead, an ogee bead, or a multiple bead may be formed in a sheet or pipe. The metal is fed between the two rollers as they are rotated.

BELT POLISHER

A machine in which a belt, coated with a fine abrasive, is carried around two pulleys which are usually mounted about two or three feet apart. It is used to polish odd-shaped parts.

BRAKES

Brakes are machines for folding or bending sheet metal to form an edge, flange, lock, angle, hem, or a simple curve.

Hand brakes and press brakes are commonly used to make both sharp bends (bends having a small bend radius) and bends having a large radius.

Box (pan) brake.—A brake whose clamping bar or leaf consists of removable fingers or jaws, which can be adjusted to form slots at desired spacing so that flanged sheets can be inserted and bent into box-like shapes.

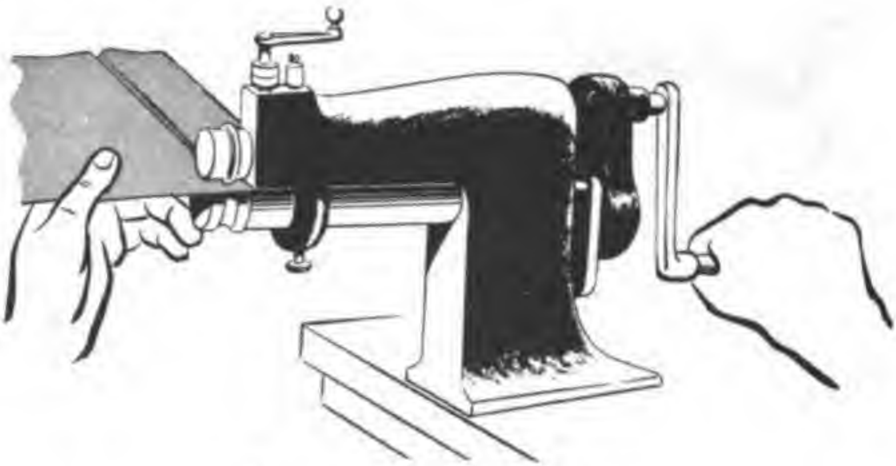


Figure 6.—Beading machine.

Hand (cornice) brake.—A hand-operated brake used to form locks and seams, to turn edges, and to make squares, angles, and bends. The bar is raised so that the sheet of metal may be pushed in to any desired distance. A stop gage is set at the angle or amount of bend to be made and then the bending leaf is raised until it strikes the stop. When it is desired to make a bend having a given radius, a wood or steel mold having this radius is clamped on the bending leaf.

Power brake.—A power-driven brake which is used to bend thick steel sheets and steel plates.

Press brake.—A power-driven press having a long narrow ram used to make simple bends in sheet metal. It differs from the hand brakes in that it uses a male die secured to the ram and a corresponding female die anchored to the base. The ram can be set for any desired stroke and thus degree of bend.

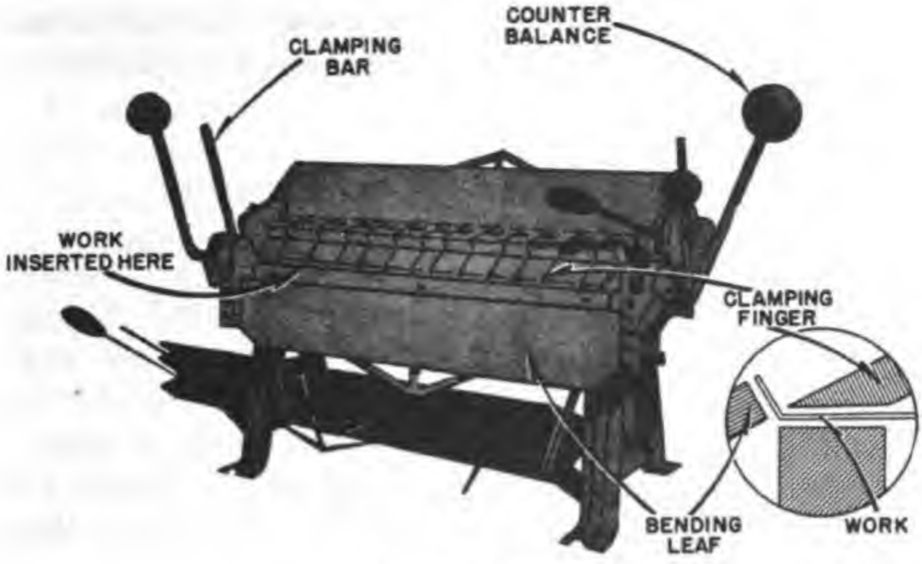


Figure 7.—Brakes.

(a) Box, or pan brake.

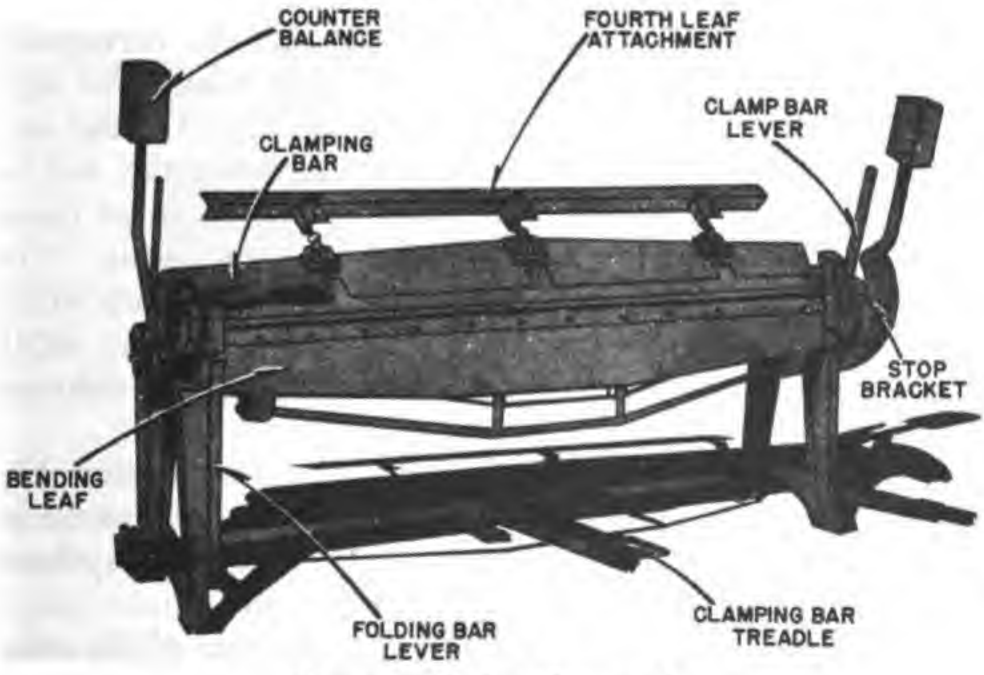


Figure 7.—Brakes, Continued.

(b) Hand, or cornice brake.

BUFFING WHEEL

A relatively soft smooth wheel made of many disks of muslin or other cloth, disks of felt, strips or disks of soft leather, or other soft material. It is mounted on a shaft or

spindle which is rotated rapidly by power. Usually a mild abrasive, such as rouge or very fine emery, is applied to the surface of the buffing wheel.

BURRING (THIN EDGE) MACHINE

A short-throated rotary machine which is especially arranged to use a pair of roll dies to turn (bend) the edge of sheet metal into a narrow burr (flange) at right angles to the sheet. It is used to turn the edges of disks for tops and bottoms of containers, to flange the ends of pipe, to form offsets, to turn edges on elbows, and to flange work for seaming or hemming. It cannot turn as wide a flange as a turning machine, but it can turn a flange with a smaller bend radius.

CRIMPING MACHINE

A short-throated rotary machine that uses corrugated rollers (roll dies) called *crimping rolls* to corrugate the edge of a sheet of metal or of a pipe, thus making it stiffer and smaller. A beading roll is often mounted on the end of the same shaft with each crimping roll so that sheet metal can be both crimped and beaded at the same time. The width of the crimp can be regulated by a metal stop which is usually clamped in place by a wing screw. The depth of the crimp can be regulated by adjusting the distance between the shafts.

When using the beading and crimping rolls together, the ends of the rollers may be tipped toward each other to produce a deep bead and a light crimp, or tilted away from each other to make a light bead and deep crimp.

The corrugations run straight across the side of the common straight-crimp roll without turning so that each corrugation produced on the sheet is at right angles to the edge of the stock.

DIE

A type of tool used to impart to a piece of stock a desired shape, form, perforation, or design. The most common kind in sheet metal work consists of a pair of cutting and/

or forming tools which are moved toward each other by pressure of a vise or press, or by hammer blows, or the like.

The movable, upper member of the two mating tools is called a punch, or male die. Its functioning surface projects and is convex. The larger member is recessed or concave and is called the matrix, female die, or often just die. It is usually stationary and supports the stock against the pressure of the male die. The matrix is a block or plate

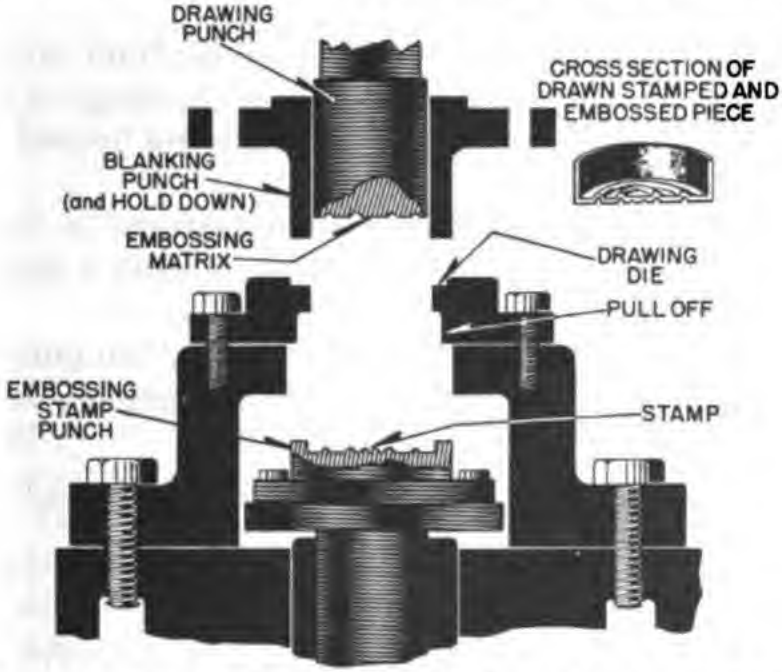


Figure 8.—Triple-action die for blanking, drawing, embossing, and stamping.

of hardened steel, or other suitable material, having perforations or depressions which mate with (line up with) the punch; thus, holes of various shapes may be punched through plates; blanks may be punched from plates, and cups, capsules, tools, and similar forms may be drawn from sheet metal. The dies may be referred to as single-action, double-action, triple-action, etc., depending upon the number of movements and operations of the punch or the matrix.

DO-ALL SAW

A trade name given to a type of band saw used for sawing metal. There is a device on the machine itself for welding

and annealing (heating and slow cooling) the saw blade. This makes it possible to break the blade, insert it through a hole in the center of the work, weld the blade anew, make the desired cut, and then break and remove the blade again. A do-all saw can also be used for filing.

DRILL

A pointed tool that is rotated to cut holes in material. Its common forms are as follows:

1. A cylindrical hardened steel bar having from one to four straight or spiral flutes (grooves) running its length, and a conical point with cutting edges formed by the ends of the flutes.
2. A hardened steel bar whose cutting end is flattened like a chisel and often beveled to form a triangular point.
3. A flat bar with a beveled end on which two grooves are ground to form cutting tips. Commonly called a *flat drill.*

The mechanism for rotating the steel drilling tool is also usually called a drill.

DRILL PRESS

An upright, stationary, powered machine for drilling holes in metal, wood, or other material. The drill or bit is gripped and rotated by a set of jaws in a collar (chunk) at the end of a powered spindle and is pressed (fed) into the work by a hand-controlled lever or an automatic feed. The work piece may be centered and clamped to a table or bed, or held by hand.

ELBOW-EDGING MACHINE

A short-throated rotary machine which uses elbow rolls (roll dies) to turn or bend the edges of the short sections of sheet metal pipe so that they can be locked together to form an elbow. Elbow-edging rolls vary in shape according to the type of edge desired. Edging rolls will usually fit any standard turning or burring machine.

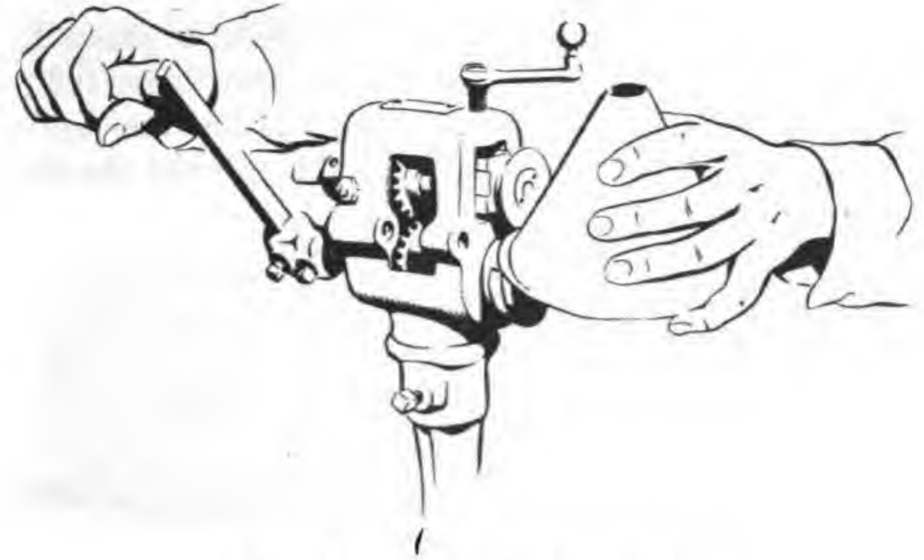


Figure 9.—Elbow-edging machine.

FILING MACHINE

A machine tool in which a file is attached to, and is stroked by, a power-driven arm or ram. The machine has a flat, square, swivel table on which the work can be mounted for filing. This machine simplifies filing by stroking the file at a constant rate and pressure, and by providing a flat, square surface on which the piece being filed may be moved around and still be kept square and in line with other parts.

FLANGING MACHINE

A machine that uses a high-speed plunger (similar to a piston) to bend up small portions of the edge of a part, thus forming a flange.

FOLDING MACHINE

A hand-powered machine used to bend (fold) sheets, plates, or leaves of metal. It is used for such operations as turning edges and flanges, forming locks and seams, and for preparing the edges of sheet metal pipes, containers, buckets, boxes, and the like, preparatory to grooving.

A folding machine consists of two frames holding a very narrow flat table (bed), a bending leaf, and a bar clamp (jaw) to hold the edge of the stock. The bending leaf and often

the jaw are hinged to the table. The operator places sheet metal on the table with the edge to be bent under the jaw, clamps it, forms an angle by raising the bending leaf, releases the clamp and removes the metal. Unlike the brake,

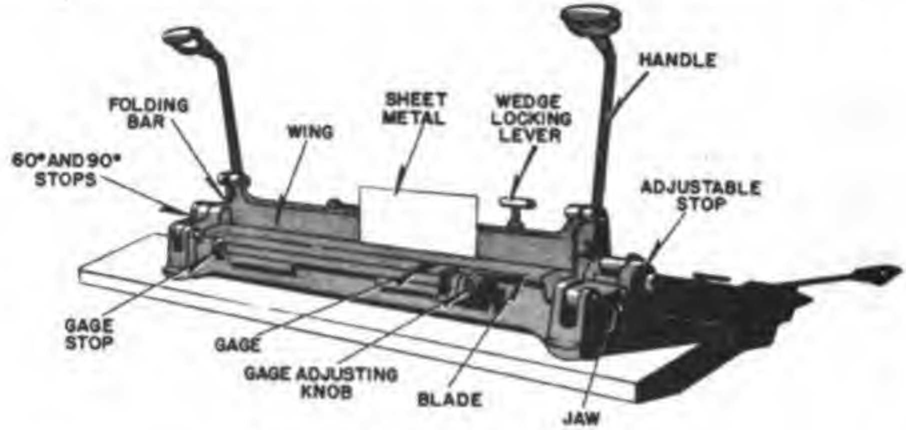


Figure 10.—Folding machine.

a folding machine commonly trims an edge or forms a lock as wide as the depth of the jaw under which the edge is inserted.

The two most commonly used types of folding machines are *bar folders* and *pipe folders*.

PIPE-FOLDING MACHINE

A folding machine which is so constructed that locks can be folded (flanges bent) either on flat sheets or on stock that has previously been formed into a cylindrical shape (pipe).

ROLL-FORMING MACHINE

A machine used to form (roll) flat stock into a cylinder, pipe, ring, air scoop, the leading edge of a wing section, or other object having a simple curve. A roll-forming machine consists of three long steel rolls, two housings or frames for holding the ends of the rolls, gears which connect the rolls, means for adjusting the distance between the rolls, and power for rotating the rolls.

The two driven front rolls grip the flat stock and force it against the rear roll which bends it up into a curve. The

top grinding roll usually has grooves for curving work having inside wire edges.

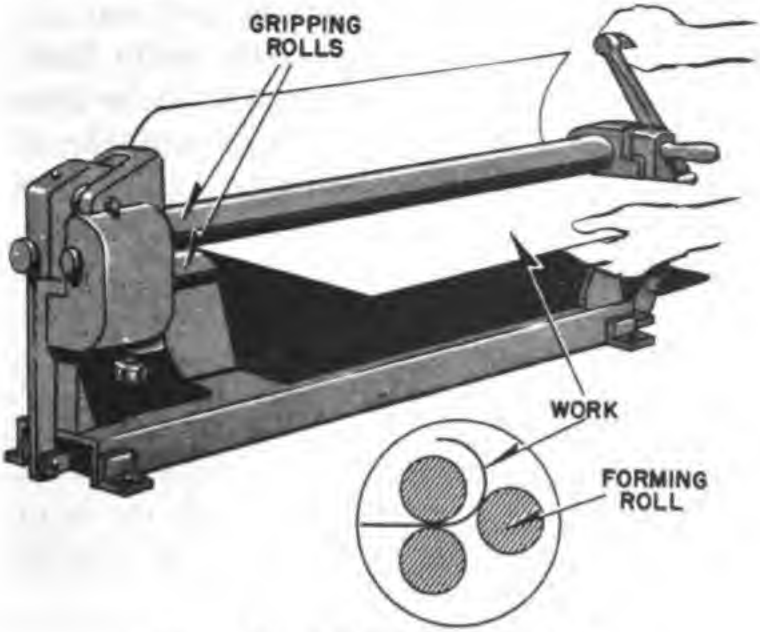


Figure 11.—Roll-forming machine.

GROOVING MACHINE

A machine used to clamp locks or seams by pressing them down into a groove flush with either the inside or the outside

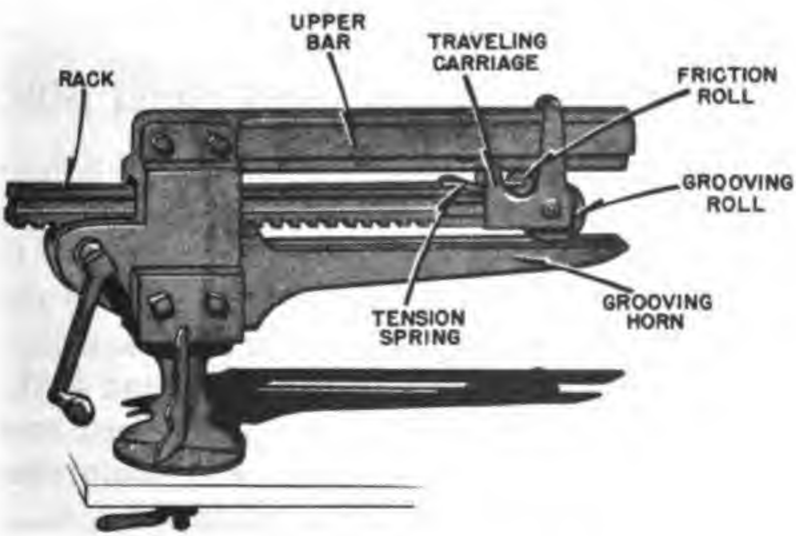


Figure 12.—Grooving machine.

surface of the sheet metal part. The two flanges are formed by roll dies and hooked together. The joint is held stationary on the horn (supporting arm of the machine) and a power-operated roller (wheel) is rolled along the seam lengthwise. A grooved horn is used when the seam is to be pressed to the inside of the work and flush with the outside surfaces. A grooved wheel is used when the seam is to be pressed to the outside.

FAST-HITTING RIVETING HAMMER

A pneumatic riveting hammer which delivers from 2,500 to 5,000 blows per minute (b. p. m.). Compared with similar slow-hitting riveting hammers, it usually has a shorter cylinder, a shorter hammer stroke, and with the same bore, delivers a lighter blow. As there is less jar or rebound, this hammer is easily held on the rivet.

ONE-SHOT RIVETING HAMMER

A large, heavy, powerful pneumatic riveting hammer which is so designed that it hits one hard blow each time the trigger is pulled. It is used in riveting structural members and heavy sheets which can be backed up adequately when upsetting (heading) the rivet with one or two blows. It cannot be used on thin sheets.

PNEUMATIC RIVETING HAMMER (RIVET GUN)

A hammering mechanism which is powered by compressed air fed from a compressed-air storage tank through a flexible line. A tubular sliding valve directs the flow of air first to the front and then to the rear end of a cylinder so that the piston (plunger of hammer) is blown rapidly back and forth in the cylinder. On the down stroke the piston strikes the gun set with considerable force, but the return stroke is cushioned by the air which is caught and compressed between the piston and the back of the cylinder.

In all except one-shot riveting hammers, the valve is automatically switched back and forth by air pressure as long as

the throttle valve is held open by the pressure of the operator's finger on the throttle lever or button. At the end of each stroke, the valve is automatically shifted both to direct the compressed air alternately in front of or in back of the piston and to open the other end of the cylinder chamber to the exhaust ports.

When heading rivets the set is placed firmly against the rivet head or tip, a heavy bucking bar is placed against the other end, and the tip upset by one shot (burst of blows) of the rivet gun.

Pneumatic riveting hammers are commonly described according to the frequency of their blows as one-shot, slow-hitting, or fast-hitting. The speed (blows per minute) is closely related to the length of the stroke and the force developed as well as to the air pressure.

Pneumatic riveting hammers with the common piston grip handles give good balance and ease of control. For use in close quarters and where obstructions are encountered, hammers are designed (1) with an offset handle, (2) with the rear end bent at a slight angle with the chamber (revolver handle), (3) without a handle (push-button type), (4) with a small offset push button handle on a short cylinder having a large bore (corner or close-quarters riveter).

POWER HAMMER

A high-speed, adjustable, power-driven hammer. Its basic parts are a frame, a hammer die, a work-supporting anvil or die, and a mechanism which connects the hammer to the power source.

The hammer can make approximately 1,200 blows per minute, and the force of the blows can be adjusted by a foot pedal. This hammer is used to raise double curves, form flanges, rivets, scarves (bevels), or to flatten sheet metal.

HOLE SAW

Essentially a short tube with saw teeth cut on one end and a shank attached to the other. Usually a drill is mounted in the center of the shank and projects slightly

below the edge of the saw. Thus the drill can both drill the pilot hole and, serving as a pilot pin, hold the saw in the desired location. Such saws are used to cut lightening holes and similar round openings.

JOINTER

A machine tool that shaves or planes off surfaces. It is used on wood, plastics, and softer metal stock. The jointer consists of four main parts—a power source; a flat table (bed) with a slot in it; a rotating cylinder, with two or more hardened steel cutting blades set lengthwise in its surface (cutting head), so positioned that the cutting edges of the blade protrude through the slot; and a movable guide, attached to the table at right angles to the cylinder.

PITTSBURGH LOCK MACHINE

A powered machine which uses a series of sets of roll dies to form the double part of the Pittsburgh lock ready to receive the flange. The sheet metal feeds through the machine and comes out on the other side with the lock formed and ready to be hooked together and clamped down, usually in a grooving machine. Many Pittsburgh lock machines also have double seaming rolls and edging rolls.

NIBBLING MACHINE (NIBBLER)

A machine that has a die and a vertical cutting blade that travels up and down at a relatively high speed. The stroke is longer than that of the Unishear, and it is adjustable. Nibblers are used to cut mild steel up to a thickness of ½-inch, and to cut circles and curves of complex shapes in heavy sheets. The machine operates on the shearing principle and leaves rough edges.

PRESSES

Machines whose mechanical advantage is used to exert controlled pressure. The press may be mechanical, depending upon levers, screws, or gearing to apply the necessary

force, or it may be hydraulic depending upon fluid pressure.

BENCH PRESS.—A small hand-operated brake or press mounted on a workbench, used for bending, shaping, and forming small pieces of sheet metal.

HYDRAULIC PRESS.—A press exerting great but controlled pressure. Its basic parts are two cylinders, one large and one small. The smaller cylinder acts as a pump. Liquid from a reservoir fills the smaller cylinder and is forced by the pump action into the larger cylinder, a check valve preventing its return. Since liquids cannot be compressed, and since pressure applied to an inclosed liquid is carried to all parts of it with equal force, the pressure that can be exerted by the large piston is as many times greater than that of the small piston as the area of the large one is larger than the area of the other. So, if the area of the larger piston is 100 times that of the smaller pump piston, it will exert a force 100 times as great.

Large hydraulic presses are used in aircraft production for power forming sheet metal parts. The work is done either by using matched male and female dies of wood, masonite, steel, or zinc, or by using a die and thick, heavy rubber blankets or pads which form (force) the metal around or into the die.

PUNCH PRESS.—A power press consisting of a bed or bolster (base) and a mechanically operated ram. The ram engages with the punch (male portion) of a die, forcing it into the fixed or female portion of the die to shear sections out of stock or to form shaped parts from a blank.

In quantity work, such as punching holes in baffle plates for fuel tanks, a *rotary punch* is used.

ROTARY MACHINE

A machine designed to rotate a matched pair of roll dies in order to press into the desired shape sheet stock that is fed between them, as clothes are fed between the rollers of a clothes wringer. The clearance between the two rolls can be adjusted usually by a small crank and screw arrangement on top of the machine.

A frame holds two shafts upon which are mounted the roll dies, meshing gears, and provisions for rotating the shafts. An adjustable stop gage is usually provided for the work to ride against and thus fix the depth at which the sheet passes between the rolls.

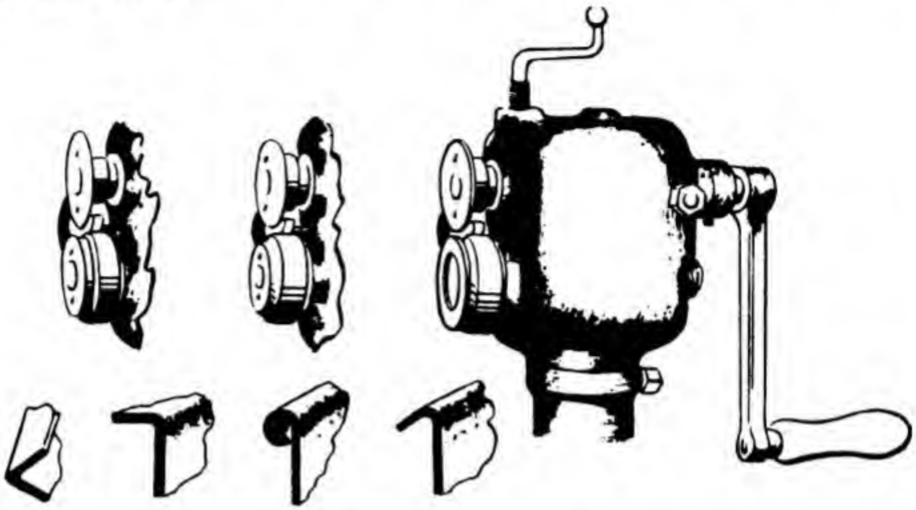


Figure 13.—Rotary machine.

The common rotary machines are burring machines, beading machines, crimping machines, elbow-edging machines, turning machines, and wiring machines. Rotary shears and setting-down machines work on the same principle and are sometimes classed as rotary machines.

SANDER (SANDING MACHINE)

A machine which uses the abrasive action of sand or similar materials to smooth or clean surfaces. The most common types of sanding machines are:

1. A machine which blows grains of sand or similar abrasives in a blast of air against the surface being sanded. This sand-air blast is directed by a nozzle to the desired part of the surface being sanded.
2. A belt sander, which consists of a belt moving over two pulleys, one of which is power-driven. The outside of the belt is coated with sand, emery, carborundum, or a similar abrasive having the desired degree of fineness.

3. A disk sander, which consists of a disk rotating on its axis, and having a disk of sand-paper fastened to the flat side.
4. A drum sander—an abrasive grit-coated cylinder with provision for mounting it on a power-driven shaft.

SETTING-DOWN MACHINE

A machine for closing seams by the use of two steel wheels (roll dies) set at an angle to each other and with their edges rolling on each other. The two rolls (wheels) are forced to rotate together by means of meshing bevel gears on the back of each roll. In some machines, the upper roll is vertical and its edge is pressed against, or opposed by, the side of a horizontal roll. In others, both upper and lower beveled rolls are inclined toward the frame at the same angle.

Flanges are formed on the outside of two parts usually by a burring machine. The flanges are hooked together, and then one flange is set-down (forced down) on the other, by the setting-down machine. This forms a tight, smooth, single seam which is then folded over, by hammering or in a special machine, to form a double seam.

SHEARING MACHINE

A machine, either powered or hand-operated, used to cut sheet metal. The sheet is held under a cutting blade which is usually brought down by the operation of a foot treadle. The blade makes a fast, straight, smooth cut to within $\frac{1}{64}$-inch tolerance (allowance).

LEVER SHEARS

Slitting shears resembling large scissors with one stationary blade attached to a base and a movable blade manually operated by a lever. Some lever shears have a punching attachment on the end of the frame opposite the shearing blades (plates).

SWAGING MACHINE

A machine for tapering, pointing, or reducing the diameter of wire rods or tubing. This is done by upsetting the stock

either between roll dies or by hammering with rapid blows between dies of suitable shape.

TURNING MACHINE

A short-throated rotary machine used on circular work to turn a narrow edge (flange) or to score a crease. The upper roll die is disk-shaped with a rounded edge. The lower roll is cylindrically-shaped with a semicircular groove running around its side near the outer end.

When using the turning machine, rolls are selected which will give the desired bend radius, the rolls are mounted and aligned or centered with each other, the gage is set back from the center of the edge of the upper roll a distance equal to the width of flange desired, the work is placed between the rolls, the upper roll is lowered until it makes a slight impression on the metal, and the rolls rotated. After each complete revolution of the work, the upper roll is lowered and the free end of the work raised.

This process is continued until the desired crease, bead, flange, or seat for wiring is made.

UNISHEAR

A trade name for a type of power shears similar to a nibbling machine. It has a high-speed, narrow, reciprocating shearing blade. It has adjustments for vertical and horizontal clearances depending on the thickness of the metal to be cut and is especially useful in cutting internal curved patterns where the radius is small—even to one and one-half inches. It may be stationary or portable.

WIRE BENDER

A machine used to bend iron bars, rods, and wires. One common type consists essentially of a bending plate and bending bar. The plate has grooves of various sizes to permit bending several wires to the same angles at the same time and is adjusted by cap screws, according to the radius desired and the thickness of the stock.

The stock is placed under the plate and over the bar. While the plate holds one part of the stock, the bar is raised with a hand lever and bends up the remaining part to the desired radius.

WIRING MACHINE

A rotary machine which uses roll dies to turn (bend) a previously formed flange down over a reinforcing wire. A wiring machine is used on sheet metal after the turning machine forms a grooved flange (seat) in the edge of the metal to receive the wire. Wire of the specified diameter is formed into a circle, placed in this seat and the flange roughly bent down with a mallet to enclose the wire. The edge is then run between the wiring rolls until the flange is forced down and completely around the wire.

TORQUE WRENCH

A wrench with jaws so arranged that a signal is given when a desired torque load is reached. The jaws may be set in ratchets which will turn freely when the load is reached.

Many torque wrenches have a scale (indicating dial) and a pointer which indicates the amount of torque exerted at a given instant.

CHAPTER 3

SHEET METAL OPERATIONS

ANNEALING

A form of heat treatment used on metal or glass, which consists of heating and cooling operations for the purpose of removing gases and stresses, inducing softness, altering ductility, toughness, electrical, magnetic, or other physical properties, or refining the grain structure.

Annealing is done by gradually heating the material to a point above the critical temperature, soaking (holding) it at this temperature for a prescribed length of time (until the grain structure has been refined), then cooling it slowly according to the method prescribed for the specific material being annealed.

Annealing differs from other forms of heat treating in the slow cooling of the metal.

BACK UP

To support material while it is being pounded, pressed, or drilled. This is done in riveting, hand-straightening, and bumping of sheet metal too large, cumbersome, or peculiarly shaped to be held against an anvil. Form blocks, dollies, and bucking bars are commonly used for this process.

BEADING

The process of forming beads on a sheet metal surface. It is usually done by rolling the metal in a beading machine. Beading is sometimes called *swaging*.

Beads are narrow raised ridges made in a sheet metal part to stiffen, straighten, or decorate it. The beads are produced by pressing, rolling, or folding the metal into shape on a brake with roll dies or in a press. Viewed from one side, the bead is a raised ridge, but from the other side, it is a trough-like depression.

Figure 14.—Beads.

BEADING TUBING

The process of forming a bead on the ends of tubing to stiffen them or to prevent hose connections from coming off. This process is performed on a roll die mechanism. The end of the tube is placed against a stop and run between the rolls.

BENDING (BRAKING)

The operation of a hand brake, a power brake, a folding machine, or the use of a hand seamer, a stake, etc., to make bends, curved or sharp-cornered, in flat sheets of metal.

Parts may be bent to shape with bar folding machines or cornice brakes, by pressing between dies, or by hammering over a wood form. The kind of material and the shape desired determine the equipment used for bending. Small sheets of metal can be bent into a curved form by hand equipment; large sheets bent to form curves require a roller or roll-forming equipment. Bending angles, such as a flange, requires the use of a cornice brake.

Examples of small parts of an aircraft that are shaped by bending are: fittings, channels, cowlings, fairings, wing tips, brass tanks, brackets, cockpit enclosures, and the like.

Bending is also referred to as *braking*.

BLANKING

The process of cutting or shearing a flat pattern (blank) from the original sheet or strip of stock, usually by means of a blanking die. It involves cutting or punching out of flat stock the flat shape from which the finished article is to be produced.

A blank is a block or sheet of partly finished material from which an object will be fashioned by machining, carving, punching, grinding, or pressing to the desired final specifications.

BUCKING

The process of backing up a material which is being pounded from the other side. A bucking bar, dolly, or the like, may be used.

BUMPING

Shaping or forming malleable metal by hammering or pounding. The metal may be supported by a dolly, a sand bag, or a die—usually a female one. The striking surface of the hammer is rounded, polished, and shaped as required.

Bumping is sometimes referred to as *raising*.

HAND BUMPING is bumping done by hand with the use of a soft hammer.

MACHINE BUMPING is that performed by a power hammer. The operator moves the sheet to be formed so that the power hammer strikes the desired spot. The anvil or arm supporting the material usually has a convex surface so that the blows of the hammer gradually impart the desired contour to the sheet of metal.

BURRING

Using a burring machine for turning edges and flanges on metal sheets or disks; removing burrs from metal with a grinding wheel, a file, or special tools.

BURRS are the ragged or turned-down edges which result from grinding, cutting, or punching a piece of metal, or the jagged edge which is produced by a cutting or abrading action on sheet metal.

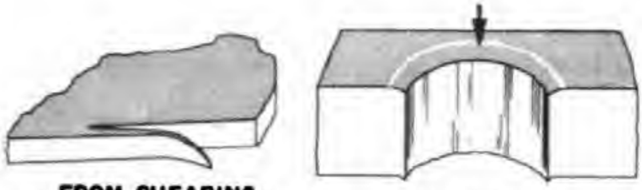


Figure 15.—Burrs.

COINING

A direct-compression process by which images, designs, or characters on a set of molds (a punch and a closed die) are pressed into the flat surface or surfaces of a blank. The imprint shows on one side only and the metal is caused to flow from some portions of the blank to others so that the article is thinner in some sections than in others.

The coining process is commonly used to decorate or mark. A simple, short-stroke press which gives comparatively high pressure is used.

COLD ROLLING

A process of forcing a piece of metal stock through two rollers in order to reduce the dimensions of the stock or change its physical qualities. The metal is squeezed into the desired shape.

Cold rolling also imparts a bright, smooth finish to the surface of the metal and increases its tensile strength. Metal sheets, steel strips, bar stock, shafting, wire, and the like are often cold rolled.

CRIMPING

Folding, pleating, or corrugating a piece of sheet metal in such a way that it will retain the imposed shape; fluting, corrugating, or compressing a metal ring to reduce its diameter (crimping is ofen used to make one end of a pipe slightly smaller so that it may be slipped into another pipe); turning down, closing down, or folding over an edge or flange.

COLD WORKING

The mechanical working or forming (bending, shaping, cutting, rolling, twisting, hammering, pressing, etc.) of metal that has not been heated. Technically the process consists of a deformation of a metal at a temperature low enough to insure strain hardening.

CORRUGATE

To produce smooth symmetrical beads or corrugations in a sheet of metal. *Corrugations* are parallel ridges and depressions in a sheet of metal; a series of alternate concave and convex beads.

CROWNING SHEET METAL

The process of forming a sheet of metal into a contour having complex curves—that is, having a change of curvature running in two directions such as a ring cowling. Crowning is sometimes spoken of as forming sheet metal to *intercepting contours*.

DIMPLING

The process of making an indentation (dimple) around a rivet hole so that the top of the head of the rivet will be flush with the surface of the metal—that is, so that the rivet will be *countersunk*. This countersinking reduces the skin drag and produces a stronger joint.

A special die is inserted in a squeeze riveter to dimple thin sheets of metal.

DYE PENETRANT TESTING

A method of detecting surface defects and subsurface defects by the use of dyes mixed with penetrating oils or suitable liquid mediums.

The penetrant may be applied by brush, spray, or bath method, as most appropriate. The penetrant is drawn into whatever cracks, porosity, laps, and seams exist in the part by capillary action, which may be intensified by the application of heat insofar as safety permits.

After parts are dried, an absorbent powder or chalk may be applied, which may aid in drawing the penetrant to the surface of the flaws. The length of time necessary for penetration and formation of a satisfactory indication after drying is dependent upon the tightness of the defect. Forging laps, fatigue cracks, and tight seams in bar stock may require time intervals as long as 24 hours. Suitable cleaning, polishing, or machining with sharp tools may be necessary to reveal some defects.

ELBOW EDGING

Turning flanges on the edges of short pipe sections which are to be locked together to form an elbow. Various types of elbow-edging roll dies are used to form the different kinds of locks. Elbow edging is commonly done on an elbow-edging machine.

EMBOSSING

Forcing a blank into a raised or projecting design, pattern, or figure. The blank is hammered or pressed against a die having a counterpart (negative) of the desired relief (raised work).

Embossing is different from stamping and coining in that all portions of the formed article have the same thickness, except for minor deviations. Embossing is used to strengthen, decorate, mark, or size an article. Either open dies or closed dies may be used in the process.

EXTRUSION

The process of producing an object by forcing materials such as lead, tin, zinc, copper, aluminum, plastics, etc., through an orifice (hole) having the desired size and shape. The material is usually sufficiently heated beforehand to make it somewhat plastic but not enough to melt it.

Extrusion breaks up the cast grain structure and produces a wrought product, which has the same cross section from one end to the other, a smooth hard finish, and a strong and compact internal structure free from flaws.

FLUSH RIVETING

Riveting sheet metal so that the top of the head of the rivet is flush (even) with the surface being riveted. A depression or recess is made about the rivet hole by dimpling, by cutting a countersink, or by drawing the rivet itself with a draw set. A flat-topped countersink rivet is used.

FORMING

Changing a work piece to a desired form. In sheet metal and similar work, forming includes bending, folding, braking, pressing, bumping, spinning, or simply forcing the material into the desired contour, but it does not include shearing, piercing, blanking, or other cutting operations.

The term is sometimes limited to the forcing of materials into complex or multicurved contours—the simpler processes being referred to as bending, braking, or folding.

FORMING RADII.—Bending sheet metal or tubing to a simple curve. Radii are normally formed with a hand or power brake or on a forming block made of wood or metal. They may be formed by the use of presses or by bumping. A simple bend, curving in one direction only, is called *radii forming* as distinguished from *contour forming*.

HAND FORMING.—Rolling, bumping, or pressing metal into definite curves or contours by hand; bending flanges on the edges of parts or around lightening holes by hand; forming of stiffening beads and the like by means of hand form blocks, mallets, hammers, or blackjacks.

MACHINE FORMING.—Forming performed by such machines as power presses, power hammers, drop hammers, brakes, folding, and similar machines.

FORMING TUBING.—Making tubing either by drawing (forcing) bar stock through suitable dies or by bending sheet stock into cylindrical shapes and welding along the seams.

AGE HARDENING (NATURAL AGING)

A precipitation hardening process that consists of heating a metal to a high temperature, soaking the metal at this temperature for a period of time, and then letting it cool

slowly and stand (age) at atmospheric or room temperature until the precipitation (separation) of a portion of its alloying elements is complete.

Aging toughens and hardens a metal by allowing it to assume its most permanent internal structural adjustment. It is particularly useful for hardening aluminum alloys. Temperatures below freezing (32° F.) will retard aging.

Some alloys that do not respond to natural aging may be aged artificially by subjecting them to high temperatures.

WORK HARDENING

Any mechanical process which results in a condition of hardness being set up in the metal subjected to the process. Work hardening consists of repeatedly applying a mechanical force, such as pressing, rolling, hammering, bending, twisting, etc., to the metal. This force sets up stresses which resist the outside forces. Hot or cold metals may be work-hardened.

HEADING RIVETS

A process of forming a second head on the shaft of rivets. The original, or manufactured head, is struck by blows from a hammer or rivet gun; the second head is formed on the shank of the rivet by backing up the shank with a dolly or bucking bar. This process clamps the material being riveted (sheet metal, fabric, leather, etc.) between the two heads of each rivet.

HEAT TREATMENT

Any method employing controlled heating and cooling of metals to develop the desired hardness or softness, ductility, tensile strength, and grain structure.

Annealing, normalizing, tempering, and hardening are all heat treatment processes. Quenching (rapid cooling) in oil, water, brine, or air is a part of various heat treatment processes.

Ferrous metals such as iron and steel and some non-ferrous metals such as copper and aluminum may be succesfully heat treated, the method used depending upon the kind of metal and results desired.

HOBBING

The process of forming a die or mold cavity by forcing a hob into a soft steel blank which is then trimmed to size, hardened, and polished.

A *hob* is a master model or pattern made of hardened steel. It is used to sink the desired shape of a die or mold into a soft steel block.

LAYOUT

Planning, developing, and marking full size patterns or templates for shopwork; scribing or otherwise marking points or lines on the surface of stock to indicate the position and shape of portions to be cut, bent, punched, formed, or to have similar work performed on it.

MAGNAFLUXING (MAGNETIC TESTING)

A process for discovering flaws or cracks in ferrous metals. The part being inspected is magnetized (made a magnet) and covered with iron filings or, more commonly, with a solution containing small particles of an iron oxide. In the wet method, any cracks or seams will cause an opposite polarity on each side of the defect, the iron oxide will collect and form a black identifying line. Cracks so small that they cannot be detected with a microscope show up plainly with this process. The parts must be demagnetized after the inspection.

X-ray testing is now supplanting magnafluxing. X-rays are passed through the metal to record a picture of the internal structure of the metal or material on photographic plates.

The X-ray test will show defects whose thickness is not less than 2 percent of the thickness of the metal examined, but will not disclose a very thin lap normal to the direction of the rays.

MAGNETIC EXAMINATION OF METALS (DRY METHOD)

Determining flaws at or near the surface of a ferro-magnetic metal by magnetizing the metal or member to be tested and

then dusting dry, fine, iron particles onto the surface. Flaws on or near the surface of the metal will cause an increase in the magnetic flux at that point, with a resultant ridge of the metallic powder.

The magnetic examination is not of much use for flaws at a depth greater than ⅛ inch below the surface of the metal.

MASKING

Covering a surface with protective material, such as heavy wrapping paper backed with an adhesive, to protect the surface from damage. Plastic sheets are masked before installation or fabrication to protect them from scratches, abrasions, and other mechanical injury.

MICROSCOPIC INSPECTION FOR METAL DEFECTS

A test which consists of cutting or sectioning a part which is suspected of having a defect and examining the section under a microscope. Although it is a destructive test, it is the best method for determining in detail the character of a defect. It is used in determining the cause of a defect, such as overloading or defective crystalline structure.

PEENING

Stretching metal by hammering or rolling the surface. Peening is used to compress babbitt inserts so that they will fit tightly in a bearing, to straighten bars by stretching the short or concave side, to upset or form a head on a bar, or to bend or flatten a fold or ridge in a sheet of metal.

In the sheet metal shop, to peen often means to set-down with a setting hammer.

PLANISHING

Compressing, flattening, and smoothing a metallic surface by lightly hammering or rolling it. A metal part may be planished to produce the desired finish, or to bring the part more exactly to the desired shape and size. It is sometimes done to remove burrs, dents, wrinkles, and ripples, or to smooth and straighten sheet metal.

Planishing may be done with a planishing hammer, roll dies, or in a short-stroke, fast-running press. Round sections of a part are usually planished in a press by turning the forging between a pair of polished flat dies.

PRESSING

Forming sheet metal parts by forcing (pressing) flat sheets of metal into molds or dies. It is essentially the same as stamping, except that the pressing process uses a slow, steady stroke or blow in forming a large section. Hydraulic, mechanical, and hand-operated presses are used.

COLD PRESSING.—Forming designs on thick metal that is not preheated. The designs are formed in the surface of the metal by a powerful press and dies.

HOT PRESSING.—Forming designs on a metal slug or billet (blank) which has been heated to forging heat before being placed in the die. This results in much less pressure on the die than cold pressing.

DIAMOND RIVETING

A symmetrical arrangement of rivets on either side of a butt joint connecting two flat bars end to end, or a flat bar to a gusset plate so that maximum strength is obtained. The arrangement begins with one rivet in the first row, two rivets in the second row, three in the third, etc., until the required number is reached.

Figure 16.—Diamond riveting.

SKIN RIVETING

The process of fastening the skin of an airplane to the stringers, longerons, ribs, rings, and bulkheads by means of rivets.

Flush riveted joints must be made so that a smooth surface will result. Raised rivet heads increase the drag or resistance to the progress of the plane.

SEAMING

The process of joining two overlapping edges of sheet metal.

GROOVED SEAMS are widely used in the fabrication of such cylindrical and conical shaped objects as tanks, cans, and funnels. The *seam allowance* is equivalent to three times the seam width (half on each edge). To fold, set the bar folder for seam width minus the metal thickness.

LAP SEAM.—Made by lapping the edges of two pieces of metal one over the other, usually followed by soldering, riveting, or both.

SET-DOWN (TIGHTEN DOWN: CLOSE)

To press together tightly the interlocked or folded parts or flanges of a lock, seam, hem, or other edge. The partly formed edge may be set down by peening with a setting hammer, or by pressure from a machine such as a setting-down machine.

SETTING RIVETS

Placing the hole in a rivet set over the shank of the rivet that is in place and then lightly tapping the rivet into the set, thus drawing the sheets close together and forcing the head snugly against the outside sheet.

SHAPING SHEET METAL

Cutting out blanks from a flat piece of stock. The blanks are later formed into finished parts. Hence shaping is to be distinguished from forming.

The equipment commonly used to shape stock includes band saws, blanking dies, circular shears, hydraulic presses, nibbling machines, power shears, routers, and Unishears.

SHOOTING RIVETS

Heading rivets with a pneumatic riveting hammer.

SHRINKING

Decreasing the area of one part of a sheet of metal in order to absorb the excess material which results when a flange is formed on a curved edge, or at the meeting point of two folds on straight edges (as at the corner of a sheet), or when the shape of a part is otherwise changed.

Sheet metal may be shrunk with a shrinking machine, by a power hammer, by skilful hand-hammering, with shrinking blocks, or by sudden cooling after heating.

SKIN FITTING

Bending and manipulating (working) a section of sheet metal skin so that it fits snugly at the proper place against the ribs, spars, rings, bulkheads, longerons, stringers, and other contacting structural members, without buckling, oilcanning, or undue strains. If the section has been cut with a template or with a damaged original section as a pattern, the rivet holes have been drilled in the structural members, in which case the holes in the sheet must be alined with (matched to) the rivet holes in the members. The holes may be drilled in the sheet after it is fitted to the structure.

SLITTING

Cutting a slit (long narrow opening) in material. The slit is usually started at one edge of a sheet and continued straight across until a relatively narrow strip is cut off one side.

Rotary shears, slitting shears, or lever shears may be used for slitting long work, and squaring shears, lever shears, hand shears or snips, for cutting shorter slits.

SOLDERING

Sealing and securing a joint between two metal pieces by applying solder to the joint. The solder is melted and spread over the adjoining surfaces with a soldering iron or a jet of flame. It does not fuse with metal surfaces, but adheres to them.

Soldering produces a weaker joint between metal surfaces than any other method of joining. Soldering is especially used to make airtight joints of sheet metal that do not have to withstand much pull or vibration, and to seal electrical connections.

The metals commonly soldered are iron, tin, copper, brass, and galvanized iron. Aluminum also may be soldered, but the method, flux, and solder used are somewhat different from those used on other metals. All soldering operations require use of a flux.

Soft soldering is used to join such metals as copper, brass, and galvanized iron sheet metal. (Soft solder—50-50—is available in bar, ingot, or wire form, and has as its main alloying elements tin and lead; it has a melting point of 360° F.).

Tinning a copper.—Tinning requires the point surfaces to be flat and smooth, which may be done by filing. Tinning is accomplished by heating the copper sufficiently to melt solder, then briskly rubbing all surfaces of the point on a block of sal-ammoniac while simultaneously dropping several tears of solder to the point.

SWEAT SOLDERING (SWEATING)

A method of soldering in which the parts to be soldered are first tinned and the melted solder drawn between the surfaces to be soldered by capillary action. Sometimes a soldering iron is used and sometimes a neutral gas flame (torch) is used to melt and flow the solder in the joint, the latter being used especially in silver soldering.

SPINNING

A process used to form a flat blank or tube of sheet metal (usually circular) into such symmetrical hollow shapes as cup, cone, cylinder, and the like. Spun pieces have cross sections that are circular in shape. The center of the blank is firmly clamped between a spinning chuck (form) having the desired shape, and a block of wood called a *follower*. The chuck is mounted on the spindle of a very high-speed

lathe and the follower is strongly forced toward it by the tailstock. Thus, when the spindle of the spinning lathe is rotated at the desired speed, the chuck, blank, follower, and tail center all revolve at the same rate. A smooth spinning tool is pressed against the rotating blank so that it is gradually forced back, and then other spinning tools are used to gradually force it down around the chuck and thus into the desired contour.

SQUARING

A process in which two adjacent surfaces or edges of a solid block or sheet of metal or other material are cut or trimmed so that they will form a right angle—that is, they are square with respect to each other.

STAMPING

Forcing lines of letters, figures, or decorations into a smooth surface with a stamp (die) having a sharp projecting outline in the desired design. The stamping tools, roller stamping dies, or hardened punch, on which the desired figure has been cut in relief, are often used to mark articles with identifying data, numbers, trademarks, names, etc. Such stamps usually cut to a depth of from 0.020 inch to 0.040 inch.

STEAMING TANKS

Cleaning tanks by spraying them with steam for a period of time. Cleaning solutions may also be introduced into the stream. Jenny cleaners are commonly used.

HAND STRAIGHTENING

The process of repairing dented, stretched, or twisted sheet metal by the use of hand tools. A common method of removing dents is to tap the concave side of the dent with a hammer having a properly shaped peen, backing up the metal with a dolly block. The workman starts tapping at the outside edge of the dent and works to the center.

If the metal is stretched, it can be shrunk by a series of heating and quenching operations. Breaks may be brazed

or welded. Holes and small depressions can be filled with solder and rubbed smooth.

SWAGING

The process of grooving, beading, or flanging a sheet of metal in order to increase its stiffness, rigidity, or resistance to bending. Swaging is commonly done by machines using roll dies.

SWEATING SHEET METAL

A form of soldering accomplished by first tinning both surfaces of the pieces to be joined, holding the pieces together and heating them with a soldering copper or flame until the solder fuses and begins to run out. The pieces are kept in close contact until the solder cools and sets.

THERMOSETTING MATERIALS

Materials which, when properly heated, soften and undergo an irreversible chemical change that results in a hardened, infusible product. This product will not soften or fuse upon later heatings short of the burning point.

TINNING

Applying a thin, closely adhering coat of solder either to the metal which is to be soldered, or to the soldering iron to prepare it for use. Tinning is often used in preparation for sweating sheet metal (sweat soldering).

TURNING

Successively bending adjacent portions of a sheet of metal to form a narrow flange, as with a turning machine.

UPSETTING

The process of shortening and thickening metal either by hammering it or by applying pressure to it. The metal may be either cold or heated.

UPSETTING A RIVET

Forming the second head of the shank of a rivet that has been inserted in the material to be riveted. The tip of the rivet is forced toward the head, thus causing the shank to bulge and form a second head. The terms *heading rivets* or *bucking rivets* are also used.

WELDING

The joining of metal parts by fusing the material together while it is in a plastic or molten state. There are several ways of producing this fusion.

WIRING

The process of turning (bending) the edges of a sheet metal part back, over, and around a reinforcing or stiffening wire. Usually the edge is bent up into a flange on a turning machine and the turning operation continued until the flange is curved around, thus forming a seat to receive the wire. The wire is placed in the groove thus formed, and a wiring machine is used to bend the flange down and around the wire so that it is completely enclosed.

CHAPTER 4

AIRCRAFT METALS

GALVANIZED IRON

Galvanized sheet metal consists of a mild steel core coated with zinc for protection against corrosion. The thickness of the protective zinc coating depends upon its intended use.

Chart 1.—Weights of zinc-coated sheets

Pounds per square foot	Ounces per square foot	Zinc-coated sheet gage	Approximate thickness
4.5312	72. 5	12	0.108-inch.
3.2812	52. 5	14	.078-inch.
2.6562	42. 5	16	.064-inch.
2.1562	34. 5	18	.052-inch.
1.6562	26. 5	20	.040-inch.
1.4062	22. 5	22	.034-inch.
1.1562	18. 5	24	.028-inch.
0.90625	14. 5	26	.022-inch.
0.84375	13. 5	27	.020-inch.
0.78125	12. 5	28	.019-inch.
0.71875	11. 5	29	.017-inch.
0.65625	10. 5	30	.016-inch.

ALUMINUM

A strong, light-weight, silvery-white metal produced principally from the ore called *bauxite*. It melts and burns to

produce a high heat. It has a high affinity for oxygen, and when exposed to moist air, it is quickly covered with a protective coat of oxide that enables it to resist further corrosive attacks. Its electrical conductivity is about 50 percent of that of copper.

Commercially pure aluminum sheet (2S) is about 99.2 percent pure. This sheet is used as a covering for aluminum alloys, and for the repair of gasoline tanks, fuel and oil lines, etc.

As a powder, aluminum is used to make the thermit mixture used in *thermit welding*. Aluminum is used as a deoxidizer in the manufacture of iron and steel and as a pigment for a durable and protective paint for both metal and wood.

2S is available in bar, wire, sheet, and tube forms. Welding rods of 2S are widely used. Its *tensile strength* is 15,500 p. s. i.; its *soft temper* tests 5 minimum (Rockwell hardness test), and its *half-hard temper*, 10 maximum. Annealing temperature is from 625° to 700° F.

ALUMINUM ALLOY

Any of a variety of alloys formed by combining commercially pure aluminum with other metals or materials, such as copper, silicon, manganese, magnesium, chromium, iron, nickel, and zinc.

Aluminum alloys age and work harden rapidly, and therefore have to be annealed often. They may be hardened by solution, heat treatment, age hardening, and cold working, depending upon the type of alloy.

Both wrought and cast aluminum alloys are used as sheet metal coverings, engine pistons, crank case sections, tanks, and for many other parts.

ALUMINUM ALLOY TEMPER DESIGNATIONS

–F. As fabricated.

–O. Annealed, recrystallized (wrought products only).

–H. Strain hardened.

- –H1, plus one or more digits. Strain hardened only.
- –H2, plus one or more digits. Strain hardened and then partially annealed.

–H3, plus one or more digits. Strain hardened and then stabilized.

–W. Solution heat treated; unstable temper.

–T. Treated to produce stable tempers other than –F, –O, or –H.

–T2. Annealed (cast products only).

–T3. Solution heat treated and then cold worked.

–T4. Solution heat treated.

–T5. Artificially aged only.

–T6. Solution heat treated and then artificially aged.

–T7. Solution heat treated and then stabilized.

–T8. Solution heat treated, cold worked, and then artificially aged.

–T9. Solution heat treated, artificially aged, and then cold worked.

–T10. Artificially aged and then cold worked.

WROUGHT ALUMINUM ALLOYS

Wrought alloy materials are designated by the letter S. Preceding this letter, a number is used for each alloy to denote its composition, such as 17S, 3S, and so on.

Wrought alloys are divided into two classes—*nonheat treatable* and *heat-treatable*.

NONHEAT TREATABLE.—Characterized by high corrosion resistance without protective treatment, ease of welding by all methods, and superior adaptability to forming. Various tempers, except O, are produced by cold rolling or drawing.

HEAT TREATABLE.—Some of these alloys show unit strengths considerably higher than those of structural steels. When properly heat treated, the corrosion resistance of these alloys is satisfactory for a wide scope of applications. All of these alloys are available in O temper, and some in W temper.

The chief aluminum alloys used for the maintenance and repair of aircraft are the wrought alloys designated as: 17S, 24S, 52S, 75S, and R303. These alloys are used for such structural parts as ribs, spars, bulkheads, and surface covering.

Chart 2.—Aluminum specifications

No.	Form	Com'l design	Army-Navy aeronautical	Federal	Army	Navy	Tensile strength in 1,000 p. s. i.
1	Bars and shapes.	2SO		QQ-A-411	57-151-2	46-A-3	15.5 max
2	Bars and shapes.	3SO		QQ-A-356		46-A-6	19 max
3	Shapes	14SO	AN-A-8				35 max
	Shapes	14ST	AN-A-8				60-68
4	Bars and shapes.	17SO		QQ-A-351	57-152-4	46-A-4	35 max
	Bars and shapes.	17ST		QQ-A-351	57-152-4	46-A-4	55 (Bar) 50 (Shape)
5	Bars and shapes.	24SO		QQ-A-354	57-152-5	46-A-9	35 max
	Bars and shapes.			QQ-A-354	57-152-5	46-A-9	62-70
6	Shapes	XB75SO	AN-A-11				40 max
	Shapes	XB75ST	AN-A-11				78 max

7	Forgings	14ST		QQ-A-367 (Gr. 5)	57-153	46-A-7 (Cl. 5)	65
	Forgings	17ST		QQ-A-367 (Gr. 1)	57-153	46-A-7 (Cl. 1)	55
	Forgings	25ST		QQ-A-367 (Gr. 2)	57-153	46-A-7 (Cl. 2)	55
	Forgings	A51ST		QQ-A-367 (Gr. 3)	57-153	46-A-7 (Cl. 3)	44
8	Sheet and strip.	2SO		QQ-A-561		47-A-2	15.5 max
	Sheet and strip.	23½H		QQ-A-561		47-A-2	16
	Sheet and strip.	2S3/4H		QQ-A-561		47-A-2	19 max
	Sheet and strip.	2SH		QQ-A-561		47-A-2	22
9	Sheet and strip.	3SO		QQ-A-359		47-A-4	19 max
	Sheet and strip.	3S½H		QQ-A-359		47-A-4	19.5
	Sheet and strip.	3S¾H		QQ-A-359		47-A-4	24
	Sheet and strip.	3SH		QQ-A-359		47-A-4	27

Chart 2.—Aluminum specifications—Continued

No.	Form	Com'l design	Army-Navy aeronautical	Federal	Army	Navy	Tensile strength in 1,000 p. s. i.
10	Sheet and strip.	24SO	AN-A-12	QQ-A-355	57-152-6	47-A-10	35 max
	Sheet and strip.	24ST	AN-A-12	QQ-A-355	57-152-6	47-A-10	62
	Sheet and strip.	24SRT	AN-A-12	QQ-A-355	57-152-5	47-A-10	69
11	Sheet and strip.	Alclad 24SO	AN-A-13	QQ-A-355	AAF 11067	47-A-8	33 max
	Sheet and strip.	Alclad 24ST	AN-A-13	QQ-A-365	AAF 11067	47-A-8	56-62
	Sheet and strip.	Alclad 24SRT	AN-A-13	QQ-A-355	AAF 11067	47-A-8	62-66
12	Sheet and strip.	61SO	------	QQ-A-327	AAF 11326	------	22 max
	Sheet and strip.	61ST	------	QQ-A-327	AAF 11326	------	42

13	Sheet and strip.	XA75SO	AN-A-9				40 max
	Sheet and strip.	XA75ST	AN-A-9				70
14	Sheet and strip.	Alclad XB75SO	AN-A-10				36-38 max
	Sheet and strip.	Alclad SB75ST	AN-A-10				70-72
15	Fabricated parts.	Alclad 24S-T80			AAF 11354		60 & 62
	Fabricated parts.	Alclad 24S-T81			AAF 11354		64 & 67
	Fabricated parts.	Alclad 24S-T84			AAF 11354		64 & 71
	Fabricated parts.	Alclad 24S-T86			AAF 11354		67 & 70
16	Tubing	2SO		WW-T-783	57-186-1	44-T-19	15.5 max
	Tubing	2S1/2H		WW-T-783	57-186-1	44-T-19	16
	Tubing	2S3/4		WW-T-783	57-186-1	44-T-19	19
	Tubing	2SH		WW-T-783	57-186-1	44-T-19	22
17	Tubing	3SO		WW-T-788		44-T-20	19 max
	Tubing	3S1/2		WW-T-788		44-T-20	19.5
	Tubing	3S3/4		WW-T-788		44-T-20	24
	Tubing	3SH		WW-T-788		44-T-20	27

Chart 2.—Aluminum specifications—Continued

No.	Form	Com'l design	Army-Navy aeronautical	Federal	Army	Navy	Tensile strength in 1,000 p. s. i.
18	Tubing Tubing	17SO 17ST		WW-T-786 WW-T-786	57-187-1 57-187-2	44-T-21 44-T-22	35 max 55
19	Tubing Tubing	24SO 24ST		WW-T-785 WW-T-785	57-187-2 57-187-2	44-T-28 44-T-31	35 max 64
20	Tubing	52SO		WW-T-787	57-187-3	44-T-32	35 max
21	Tubing Tubing	XA75SO XA75ST	AN-T-32 AN-T-32				40 max 70
22	Castings	43	AN-QQ-A-405	QQ-A-601 (C1.2)	AAF 11311	46-A-1 (C1.1)	17
23	Castings	195	AN-QQ-A 390	QQ-A-601 (C1.4)	57-72-5	46-A-1 (C1.4)	
24	Castings	356	AN-QQ-A 394	QQ-A-601 (C1.3)	AAF 11308	46-A-1 (C1.3)	

Chart 3.—Rivet lengths for raised head rivets

Diameter in inches		3/32	1/8	5/32	3/16	1/4
Length of rivet in inches	Dash No. for rivet	Max. grip	Max. grip	Max. grip	Max. grip	Max. grip
1/8	−2	0	0	0	0	0
3/16	−3	.070	.031	0	0	0
1/4	−4	.133	.094	.055	.016	0
5/16	−5	.195	.156	.117	.078	0
3/8	−6	.253	.219	.180	.141	.062
7/16	−7	.305	.281	.242	.203	.125
1/2	−8	.353	.344	.305	.266	.188
9/16	−9	.398	.406	.367	.328	.250
5/8	−10	.443	.464	.430	.391	.312
11/16	−11	.490	.516	.492	.453	.375
3/4	−12	.542	.564	.550	.516	.438
13/16	−13	.604	.606	.602	.578	.500
7/8	−14	.665	.644	.650	.641	.562
15/16	−15	.725	.685	.692	.698	.625
1	−16	.788	.731	.730	.746	.688

Chart 4.—Allowable bearing strength of 24ST aluminum alloy sheet. (Fbr=90,000 p. s. i.)

Diameter of rivet or pin (inches)	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
0.014	78	118	157	196	236	315	393	472
0.016	98	135	180	225	270	360	450	540
0.018	101	151	202	253	303	405	506	607
0.020	112	168	225	281	337	450	562	675
0.025	140	210	281	351	421	562	703	843
0.032	180	269	360	449	540	720	900	1080
0.036	202	303	405	506	607	810	1012	1215
0.040	225	337	450	562	675	900	1125	1350
0.045	253	379	506	632	759	1012	1265	1518
0.051	286	430	573	716	860	1147	1434	1721
0.064	360	539	720	899	1080	1440	1800	2160
0.072	405	607	810	1012	1215	1620	2025	2430
0.081	455	683	910	1138	1366	1822	2278	2733
0.091	511	767	1023	1279	1535	2047	2559	3071
0.102	573	860	1147	1434	1721	2295	2868	3442
0.128	720	1079	1440	1799	2160	2880	3600	4320
5/32	878	1317	1757	2195	2635	3514	4393	5271
3/16	1054	1581	2109	2635	3164	4218	5273	6328
1/4	1406	2108	2812	3514	4218	5625	7031	8437

Chart 5.—Allowable bearing strength of 24ST alclad aluminum alloy sheet. (F_{br}=82,000 p. s. i.)

Diameter of rivet or pin (inches)	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
0.014	71	107	143	179	215	287	358	430
0.016	82	123	164	204	246	328	410	492
0.018	92	138	184	230	276	369	461	553
0.020	102	153	205	256	307	410	512	615
0.025	128	192	256	320	384	512	640	768
0.032	164	245	328	409	492	656	820	984
0.036	184	276	369	461	553	738	922	1107
0.040	205	307	410	512	615	820	1025	1230
0.045	230	345	461	576	691	922	1153	1383
0.051	261	391	522	653	784	1045	1306	1568
0.064	328	491	656	819	984	1312	1640	1968
0.072	369	553	738	922	1107	1476	1845	2214
0.081	415	622	830	1037	1245	1660	2075	2490
0.091	466	699	932	1165	1399	1865	2331	2798
0.102	522	783	1045	1306	1568	2091	2613	3136
0.128	656	983	1312	1639	1968	2624	3280	3936
5/32	800	1200	1601	2000	2401	3202	4002	4803
3/16	960	1440	1921	2401	2882	3843	4804	5765
1/4	1281	1920	2562	3202	3843	5125	6406	7687

75S ALUMINUM ALLOY

Alcoa's 75S alloy has exceedingly high strength properties. Weight saving resulting from its use in aircraft structures is outstanding.

Yield strength of 75S is more than 50 percent greater than that of 24S alloy. 75S coating (cladding) is 4 percent of sheet thickness per side, while 24S is 5 percent per side.

R303 ALUMINUM ALLOY

Reynolds Metal Co.'s R303 aluminum alloy is also far superior to the familiar 24S. It was developed primarily for extrusions and forging stock, but it is also available in sheet form.

Non-heat treatable

TEMPERS

O—Dead soft—Annealed.

¼ H, ½ H, ¾ H — Varying degrees of strain hardening brought about by cold working.

H—hard.

DECODING

```
3  S  O
|  |  |____Dead soft
|  |_______Wrought
|__________Type of alloy

3  S  ¼H
|  |  |____¼ hard
|  |_______Wrought
|__________Type of alloy
```

Heat treatable

TEMPERS

O—Annealed.

T—Maximum hardness by heat treatment.

R—Strain hardened.

W—Metal has received the solution heat treatment.

DECODING

```
24  S  O
|   |  |____Annealed
|   |_______Wrought
|___________Type of alloy

24  S  R  T
|   |  |  |____Fully heat treated
|   |  |_______Strain hardened
|   |__________Wrought
|______________Type of alloy
```

Chart 7.—SAE steel numbering system

Type of steel	Numerals and digits
Carbon steels	1- - -
Plain carbon	10- -
Free cutting (screw stock)	11- -
Manganese steels	13- -
Nickel steels	2- - -
3.50 percent nickel	23- -
5.00 percent nickel	25- -
Nickel chromium steels	3- - -
1.25 percent nickel, 0.60 percent chromium	31- -
1.75 percent nickel, 1.00 percent chromium	32- -
3.50 percent nickel, 1.50 percent chromium	33- -
Molybdenum steels	4- - -
Carbon molybdenum	40- -
Chromium molybdenum	41- -
Chromium nickel molybdenum	43- -
Nickel molybdenum, 1.75 percent nickel	46- -
Nickel molybdenum; 3.50 percent nickel	48- -
Chromium steels	5- - -
Low chromium	51- -
Medium chromium	52- - -
Corrosion- and heat-resisting	51- - -
Chromium vanadium steels	6- - -
1 percent chromium	61- -
Silicon manganese steels	9- - -
2 percent silicon	92- -

The first digit (figure) indicates the type to which the steel belongs as:

1—carbon steel.
2—nickel steel.
3—nickel—chromium steel.
4—molybdenum steel.
5—chromium steel.
6—chromium—vanadium steel.
7—tungsten steel.
8—silicon—manganese steel.

The second and third digit indicates the approximate percentage of predominating alloying element in simple alloy

steels, except in some instances, such as several of the corrosion—and heat-resisting steels.

The last two or three digits usually indicate the average carbon content in points or hundredths of 1 percent. See chart 8.

Chart 8.—Decoding SAE numbers.

SAE 2330

2 3 30

- 30 — Approx. 0.30% carbon
- 3 — Approx. 3% nickel
- 2 — Nickel steel

SAE 6150

6 1 50

- 50 — Approx. 0.50% carbon
- 1 — Approx. 10% chromium
- 6 — Chrome—vanadium

SAE 1045

1 0 45

- 45 — Approx. 0.45% carbon
- 0 — No alloy
- 1 — Carbon steel

SAE 4130

*4 1 30

- 30 — Approx. 0.30% carbon
- 1 — Chromium
- 4 — Molybdenum

*Consult chart 9 for chemical composition and for percentages of molybdenum and chromium used as an alloy.

Chart 9.—Composition of steels used in aircraft construction

Commercial material designation	Carbon	Silicon	Manganese	Phosphorus (max.)	Sulphur (max.)
SAE 1025	0. 22–0. 28		0. 30–0. 50	0. 040	0. 050
SAE 1035	. 32– . 38	0. 15–0. 35	. 60– . 90	. 040	. 050
SAE 1045	. 43– . 50	. 15– . 35	. 60– . 90	. 040	. 050
SAE 1095	. 90–1. 05	. 15– . 35	. 30– . 50	. 040	. 050
SAE 2330	. 28– . 35	. 20– . 35	. 60– . 80	. 040	. 050
SAE 4130	. 28– . 33	. 20– . 35	. 40– . 60	. 040	. 040
SAE 4137	. 35– . 40	. 20– . 35	. 70– . 90	. 040	. 040
SAE 4140	. 38– . 43	. 20– . 35	. 75–1. 00	. 040	. 040
SAE 3140	. 38– . 43	. 20– . 35	. 70– . 90	. 040	. 040
SAE 3240	. 38– . 45	. 20– . 35	. 70– . 90	. 040	. 040
SAE 3435	. 32– . 38	. 20– . 35	. 45– . 74	. 040	. 040
SAE 4340	. 38– . 43	. 20– . 35	. 60– . 80	. 040	. 040
SAE 4615	. 14– . 18	. 20– . 35	. 45– . 65	. 040	. 040
SAE 6150	. 48– . 55	. 20– . 35	. 65– . 90	. 040	. 040
SAE 51210	. 08– . 15	. 50 Max	. 60 Max	. 030	. 030
SAE 51335	. 30– . 40	. 50 Max	. 50 Max	. 035	. 035
NE 8620	. 18– . 23	. 20– . 35	. 70– . 90	. 040	. 040
NE 8630	. 27– . 33	. 20– . 35	. 70– . 90	. 040	. 040
NE 8735	. 33– . 38	. 20– . 35	. 75–1. 00	. 040	. 040
NE 8740	. 38– . 43	. 20– . 35	. 75–1. 00	. 040	. 040
Nitralloy composition A[1]	. 38– . 45	. 20– . 40	. 40– . 70	. 040	. 050
Nitralloy composition B[2]	. 30– . 40	. 20– . 40	. 50–1. 10	. 040	. 060

[1] High core strength. [2] Free machining.

Commercial material designation	Chromium	Nickel	Molybdenum	Vanadium	Others
SAE 1025					
SAE 1035					
SAE 1045					
SAE 1095					
SAE 2330		3. 25–3. 75			
SAE 4130	0. 80–1. 10		0. 15–0. 25		
SAE 4137	. 80–1. 10		. 15– . 25		
SAE 4140	. 80–1. 10		. 15– . 25		
SAE 3140	. 55– . 75	1. 00–1. 40			
SAE 3240	. 90–1. 20	1. 65–2. 00			
SAE 3435	. 60– . 95	2. 75– . 325			
SAE 4340	. 70– . 90	1. 65–2. 00	. 20– . 30		
SAE 4615		1. 65–2. 00	. 20– . 30		
SAE 6150	. 80–1. 10			15 min.	
SAE 51210	11. 5–13. 0				
SAE 51335	11. 5–14. 0				0.95–1.35 aluminum.
NE 8620	. 40– . 60	. 40– . 70	. 15– . 25		
NE 8630	. 40– . 60	. 40– . 70	. 15– . 25		
NE 8735	. 40– . 60	. 40– . 70	. 20– . 30		
NE 8740	. 40– . 60	. 40– . 70	. 20– . 30		
Nitralloy composition A[1]	1. 40–1. 80		. 30– . 45		0.85–1.20 aluminum.
Nitralloy composition B[2]	1. 00–1. 500		. 50– . 25		0.85–1.20 aluminum. 0.15–0.25 selinum.

[1] High core strength. [2] Free machining.

Chart 10.—Carbon steel

Class	Percentage or carbon	Typical SAE steels	General use
Low carbon	0.10–0.30	1025 (mild steel)	Forgings, low stressed fittings.
Medium carbon	0.30–0.50	1035 and 1045	Good machining qualities. Small and medium sized forgings. Structural steel.
High carbon	0.50–1.05	1095 (high carbon)	Machine and hand tools.

Chart 11.—Alloy steels

SAE No.	Alloy	Aircraft uses	Characteristics
2330	Nickel	Nuts and bolts	Strong and tough.
3140	Chrome-nickel	Heat treated forgings, crankshafts, connecting rods	Strong and tough as compared to plain carbon steels.
3250	Chrome-nickel	Oil hardened parts to be machined and forged	High physical properties.
4130	Chrome-molybdenum	Fittings, tubular members	Welds, high strength, tough.
4140	High carbon chrome-molybdenum.	Heavy parts	Responds to heat treatment better than 4130.
4340	Chrome-nickel-molybdenum	Crankshafts, propeller hubs	Good physical qualities.
6150	Medium carbon chrome-vanadium.	Springs, heat treated forgings	Limited structural uses.
6195	High carbon chrome-vanadium.	Roller and ball bearings	Extremely hard.
51210	Chromium steel	Balls, races and anti-friction bearing rollers	Hard.
51335	Chromium	(Stainless) Bomb shackles, pump shafts	Corrosion resisting.

Chart 12.—Wire and sheet metal gages

Gage	B. & S. G.	B. W. G.	U. S. S. G.	N. W. G.	M. W. G.	S. W. G.
Names	Brown & Sharpe gage	Birmingham wire and stubs iron wire gage	United States standard	National	Music wire gage	British Imperial Standard wire gage
Material Applied to— / Gage No.	Sheets: Aluminum, Brass, Copper; Wire:	Tubing: Aluminum, Steel, Brass, Copper; Sheet: Spring Steel	Sheets: Steel, Terneplate	Wire: Steel, Spring Steel	Wire: Piano Wire	Sheets: Aluminum; Wire: All wire (in England)
000000	0. 5800	------------	0. 4688	0. 4615	0. 004	0. 464
00000	. 5165	0. 500(½)	. 4375	. 4305	. 005	. 432
0000	. 4600	. 454	. 4063	. 3938	. 006	. 400
000	. 4096	. 425	. 3750	. 3625	. 007	. 372
00	. 3648	. 380	. 3438	. 3310	. 008	. 348
0	. 3249	. 340	. 3125	. 3065	. 009	. 324
1	. 2893	. 300	. 2813	. 2830	. 010	. 300
2	. 2576	. 284	. 2656	. 2625	. 011	. 276
3	. 2294	. 259	. 2500	. 2437	. 012	. 252
4	. 2043	. 238	. 2344	. 2253	. 013	. 232
5	. 1819	. 220	. 2188	. 2070	. 014	. 212
6	. 1620	. 203	. 2031	. 1920	. 016	. 192
7	. 1443	. 180	. 1875	. 1770	. 018	. 176
8	. 1285	. 165	. 1719	. 1620	. 020	. 160
9	. 1144	. 148	. 1563	. 1483	. 022	. 144
10	. 1019	. 134	. 1406	. 1330	. 024	. 128
11	. 0907	. 120	. 1250	. 1205	. 026	. 116
12	. 0808	. 109	. 1094	. 1055	. 029	. 104

13	.0720	.095	.0938	.0915	.031	.092
14	.0641	.083	.0781	.0800	.033	.080
15	.0571	.072	.0703	.0720	.035	.072
16	.0508	.065	.0625	.0625	.037	.064
17	.0453	.058	.0563	.0540	.039	.056
18	.0403	.049	.0500	.0475	.041	.048
19	.0359	.042	.0438	.0410	.043	.040
20	.0320	.035	.0375	.0348	.045	.036
21	.0285	.032	.0344	.0317	.047	.032
22	.0253	.028	.0313	.0286	.049	.028
23	.0226	.025	.0281	.0258	.051	.024
24	.0201	.022	.0250	.0230	.055	.022
25	.0179	.020	.0219	.0204	.059	.020
26	.0159	.018	.0188	.0181	.063	.018
27	.0142	.016	.0172	.0173	.067	.0164
28	.0126	.014	.0156	.0162	.071	.0148
29	.0113	.013	.0141	.0150	.075	.0136
30	.0100	.012	.0125	.0140	.080	.0124
31	.0089	.010	.0109	.0132	.085	.0116
32	.0080	.009	.0102	.0128	.090	.0108
33	.0071	.008	.0094	.0118	.095	.0100
34	.0063	.007	.0086	.0104	.100	.0092
35	.0056	.005	.0078	.0095	.106	.0084
36	.0050	.004	.0070	.0090	.112	.0076
37	.0045	----------	.0066	.0085	.118	.0068
38	.0040	----------	.0063	.0080	.124	.0060
39	.0035	----------	----------	.0075	.130	.0052
40	.0031	----------	----------	.0070	.138	.0048

GALVANIC ACTION OF METALS

For insulation of dissimilar metals, refer to chapter 6, Metal Finishing and Corrosion Prevention.

STABILIZED STAINLESS

Stabilized stainless 18–8 steel, so called because columbium or titanium in the metal makes it possible to prevent the chromium carbides from precipitating. If precipitation does take place, the metal loses, to a large degree, its ability to resist corrosion.

AIRCRAFT STEEL AND ALLOY STEEL

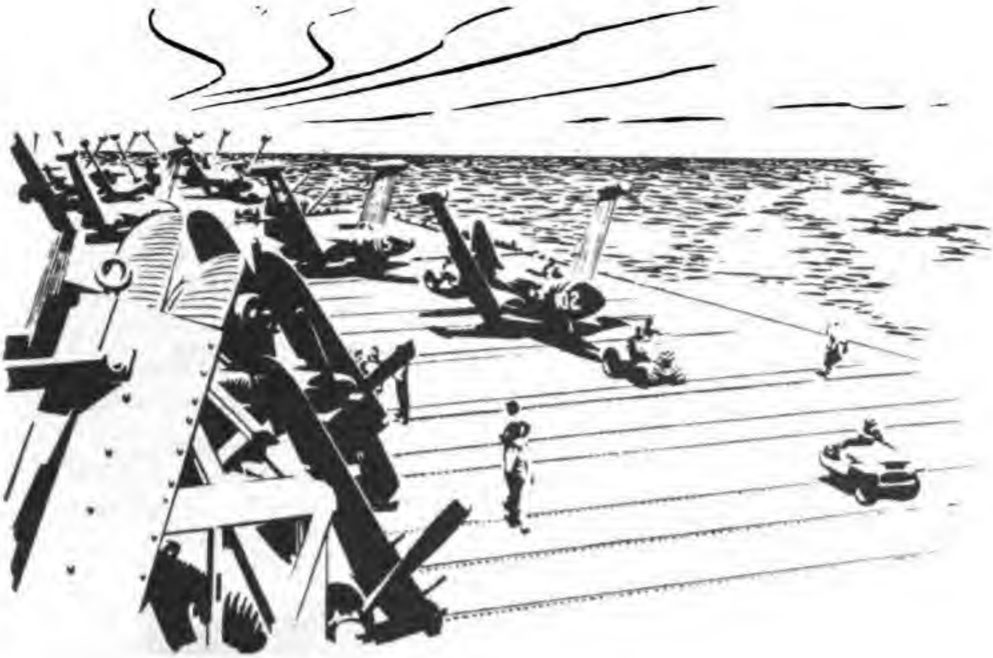
The effect of different alloys upon certain metals determines in part the metal's characteristics and the uses to which it is put. When alloyed with steel, nickel develops toughness, while chromium increases its hardness.

Ductility of metal is not altered, but the strength is increased by adding molybdenum. Molybdenum as an alloy improves the hardening characteristics of the metal as well as increasing its wear resistance and toughness.

Refer to succeeding tables for composition and typical uses of various aircraft steels.

SAE STEEL NUMBERING SYSTEM

A numbering system, developed by the Society of Automotive Engineers, whereby the composition of steel may be determined. It is a simple numerical system in which the major alloying element is identified by a number and the carbon content is indicated by two or three digits. See chart 7.



CHAPTER 5

HEAT TREATMENT AND METALLURGY

HEAT TREATMENT OF NON-FERROUS METALS

Heat treatment of metal involves various processes which are concerned with heating and cooling of metal. Each process is different so that the end result is a metal having the characteristics which are the most desirable for a particular purpose. The following tables give the specific temperatures, soaking times and cooling methods to produce the characteristics desired.

HEAT-TREATING EQUIPMENT

FURNACES.—Furnace design, size and type are determined largely by the nature of the parts to be heat treated.

Furnaces are heated primarily by electricity, although oil or gas may be used. Electric furnaces employ heating elements of the metal resistor type if the temperature range of the furnace is below 2000° F.; higher temperature furnaces require a carbon type heating element.

Salt baths of the electric type are usually heated by electrical resistors. Scaling of parts is eliminated when treated

in a salt-bath type furnace but the parts must have all evidences of salt removed upon completion of the treatment.

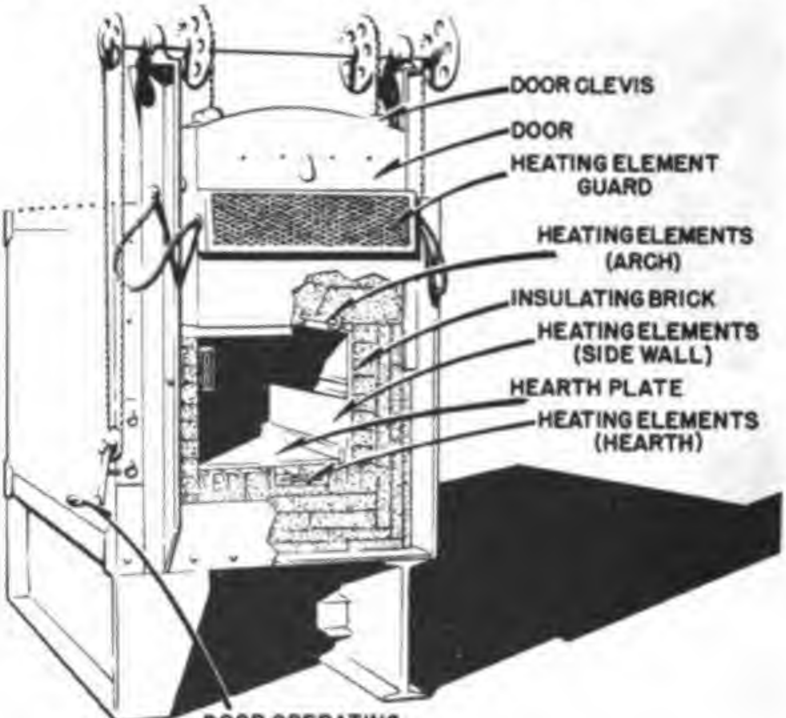


Figure 17.—Electric heat-treating furnace.

QUENCHING TANKS.—Quenching tanks should have a volume such as to assure a constant quenching temperature (room temperature). If necessary, pumps may be used to circulate the quenching media in order to maintain room temperature. The quenching tank should be located close to the furnace to make rapid transfer from furnace to quench possible.

Chart 13.—Annealing of work hardened material

Alloy	Temperature ° C.	Temperature ° F.	Soaking period	Quench
2S	344–354	650–670	Until metal is thoroughly heated.	Air.
3S	344–354	650–670		Air.
52S	344–354	650–670		Air.

Chart 14.—Annealing

Type of annealing	Temperature ° F.	Soak	Quench
Anneal of work hardened material (Except 75S).	650–670	Until parts are within.	Slow cooling.
Partial anneal of heat-treated material.	650–670	Same.	Same.
Anneal of heat-treated material (except 75S).	750–800	1 hour.	Cool 50° F. per hour to 500°—rate below 500° of no significance.
Full anneal of 75S step No. 1.	775–850	2 hours.	Air.
Step No. 2 (reheat).	440–460	2 hours.	Air.

Chart 15.—Solution heat treating temperature

Alloy	Temperature (°F.)
Wrought:	
14S and 17S	925– 950
A17S	890– 950
24S and Clad 24S	910– 930
53S and 61S	960–1010
75S and Clad 75S (Sheet)	860– 930
75S (Extruded shapes)	860– 880
4.0 Cu-1.0 Si-Mn-Mg clad sheet	925- 950
Forging alloys:	
14S	925– 945
17S	925– 950
18S	940– 970
25S	950– 970
32S	950–1010
53S	960–1010

Chart 16.—Precipitation heat treating temperature for aluminum alloys

Alloy	Soaking time (hours)	Temperature (° F.)
Wrought alloys:		
A17S–T, 17S–T, 24S–T	96	(1)
14S–T	8	345–355
	5	355–365
53S–T, 61S–T	12–20	315–325
	6–10	345–355
4.0 Cu–1.0 Si–Mn–Mg	18	310–330
	6–10	330–355
75S–T, Clad 75S–T	24	245–255
Forging alloys:		
14S	5–14	330–360
17S	96	(1)
18S	4–12	330–350
25S	6–14	330–350
32S	4–12	330–350
A51S	4–12	330–350
53S	6–10	345–355
	12–20	315–325

[1] Room temperature.

Chart 17.—Soaking time for solution heat treatment (excluding forgings)

Alloy	Time for given thickness, minutes [1]			
	Up to 0.032 inch	Over 0.032 to 0.125 inch	Over 0.125 to 0.250 inch	Over 0.250 inch
4.0 Cu–1.0 Si–Mn–Mg [2]	7	15	25	45
14S			30	60
A17S	20	20	30	60
17S	20	20	30	60
24S	30	30	40	60
Clad: [2]				
24S	20	30	40	60
53S	20	30	40	60
61S	20	30	40	60
75S	25	30	40	60
75S	20	30	40	60

[1] Soaking time begins when the load reaches the minimum heat range.

[2] Clad materials—Hold in heat treating temperature a minimum length of time to prevent diffusion of the clad coating.

Chart 18.—Soaking time for solution heat treatment of R301 (clad plate and sheet)

Metal thickness (inch)	Time (minutes)
Up to 0.032 inclusive	10
Over 0.032–0.063	15
Over 0.063–0.101	20
Over 0.101–0.250	30
Over 0.250	60

Chart 19.—Reheat treatment of clad alloys

Thickness of material (inches)	Number of reheat treatments permissible (solution heat treatment)	
	2½ percent coating, maximum	5 percent coating, maximum
Up to 0.063	None	1
0.063–0.125	1	2
Over 0.125	2	3

Chart 20.—Rockwell hardness values after 24 hours aging for heat-treated alloy 17S

Thickness of material (inch)	Rockwell numbers (red scale)				
	100 kgm. load 1/16" ball	60 kgm. load 1/16" ball	100 kgm. load 1/8" ball	60 kgm. load 1/8" ball	100 kgm. load 1/4" ball
0.024 and less					108
0.024–0.034				105	108
0.034–0.045			90	105	108
0.045–0.064		90	90	105	108
Over 0.064	60	90	90	105	108

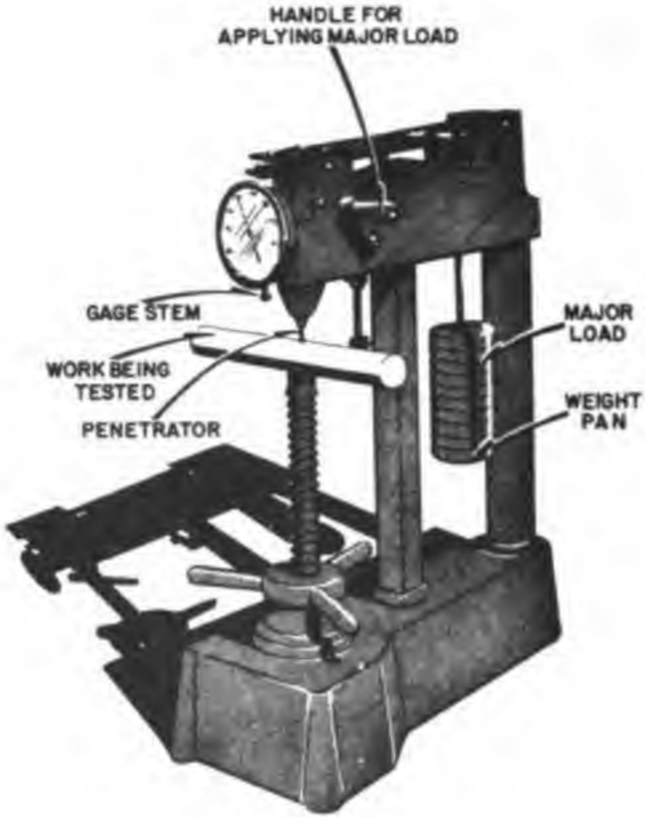


Figure 18.—Rockwell hardness tester.

Chart 21.—Minimum Rockwell hardness values after 24 hours aging for heat treated alloy 24S

Thickness of material (inch)	Rockwell numbers (red scale)							
	100 kgm. load 1/16" ball	60 kgm. load 1/16" ball	100 kgm. load 1/8" ball	60 kgm. load 1/8" ball	100 kgm. load 1/4" ball	Superficial Rockwell tester		
						45T	30T	15T
0.024 and less					109			81
Over 0.024–0.034				108	109			81
Over 0.034–0.045			95	108	109		59	81
Over 0.045–0.064		95	95	108	109		59	81
Over 0.064	68	95	95	108	109	41	59	81

Chart 22.—Brinell hardness number after 4 days aging

Alloy	500 kgm. load—10 mm. ball
17S–T	90–105
24S–T	100–120

Chart 23.—Heat treatment of rivets [1]

Alloy	Temp. °F.	Minimum soaking time	Quench
17S [2]	925–950	10 minutes	Cold water.
24S [3]	910–930	30 minutes	Cold water.

[1] Rivets may be reheat treated 15 times.

[2] Harden in 1 hour at room temperature, 1 day at 32° F., dry ice 1 week.

[3] Harden in ½ hour at room temperature, and in 1 day on dry ice.

Caution.—Do not permit the molten salt to contact the rivets. Provide special closed end tubes (2-inch to 2½-inch dia.) with removable covers, into which rivet containers may be hung with their tops below the salt level at least 4 inches.

ANNEALING COPPER TUBING WITH TORCH

The annealing temperature may be recognized by colored flashes prevalent over the metal when it reaches the annealing temperature. Heating is followed by a water quench. Cleaning copper tubing may be accomplished as indicated in chart 25.

Chart 24.—Furnace annealing of copper tubing

Tubing	Salt bath or air furance (electric)		
	Temperature of furance (°F.)	Approximate time to reach temp. (min.)	Quench (room temp.)
With no fittings.	1, 100–1, 200	10	Water.
With silver soldered fittings or with flaring.	850–900	10	Water.

Chart 25.—Cleaning annealed copper tubing

Cleaning agent	Immersion time	Rinse	Immersion time
A pickling solution 1 to 3 (by volume) of sulphuric acid and water.*	1–3 min. (10 min. max.).	Water	½ min. (agitate).
Steel wool (large tubing).	Pulled along inside tubing until all traces of scale have been removed.		

*Caution.—As a safety precaution when mixing acid and water, make sure to add the acid to the water.

MAGNESIUM ALLOY CASTINGS

Electric circulating air furances, with temperature variations of not more than 10° F., are recommended for heat treatment (solution) of magnesium castings. Types I or III require a furnace equipped to maintain a 0.3 percent sulfur dioxide atmosphere during solution heat treatment.

HEAT TREATMENT TERMS AND PROCESSES

Annealing.—Annealing is a heat treating process whereby the metal is reduced to a state of maximum softness. Annealing, in addition to inducing softness, brings about other conditions in the metal such as increased ductility, refinement of grain structure, and reduced internal stresses.

Hardening.—Hardening increases a metal's tensile strength and brittleness, but decreases its ductility and softness. It is impractical to use metal in the hard condition because of its extreme brittleness. To alleviate or reduce the brittleness, metal is tempered.

Normalizing.—Normalizing is a process used on metals to produce a homogeneous mass relative to the metal's structure, grain size, and composition.

Tempering.—The tempering (drawing) process is used to reduce brittleness and internal strains of metals resulting from the hardening process.

Case hardening, carburizing, cyaniding and nitriding are discussed under separate headings.

Chart 26.—Heat treatment of magnesium casting alloys

Type	Form	Time to reach temp. from 640° F.	Solution treating (max. temp. °F.)	Soaking time (hours)*	Quench	Aging treatment	Government Specification No.
I	Permanent mold.		810	16–24	Air	10 hrs. at 325° F.	11348.
II	Sand casting.	2 hrs.	735	8–14	Air	14 hrs. at .350° F. or 16 hrs. at 400° F. or 18 hrs. at 350° F.	AN-QQ-M-56 composition A.
IIIa	Sand casting.	2 hrs.	775	16–24	Air	18 hrs. at 350° F. or 4 hrs. at 500° F. or 18 hrs. at 350° F.	AN-QQ-M-56 composition C.
IIIb	Sand casting.		785	12–20	Air	12 hrs. at 450° F. or 16 hrs. at 400° F. or 20 hrs. at 350° F.	AN-QQ-M-56 composition C.
IIIb						8 hrs. at 325° F.	
IIIc	Permanent mold.		775	14–24	Air	10 hrs. at 235° to 350° F.	11349.
IIIc						10 hrs. at 325° F. or 4 hrs. at 599° F.	

NOTE.—*Castings with sections thicker than 2 inches may require longer times than those shown above.

Chart 27.—Operational sequence of heat-treating process

Process	Temperature [1]	Soak [2]	Method of cooling [3]
Annealing	Above critical range	According to thickness.	Slow cool.
Hardening	Critical range	Same	Quench.
Normalizing	Above critical range	Same	Still air.
Tempering	Below critical range	Same	Air.

[1] Refer to chart 31.
[2] Refer to chart 32.
[3] Method of cooling, chart 33.

CASE HARDENING

Case hardening is a process given metal parts to produce a core metal which is tough yet possesses a hard surface to resist wear. Carburizing, cyaniding and nitriding are common methods of case hardening.

Chart 28.—Carburizing low carbon steels and low carbon alloy steels

Carburizing method	Method of application
Solid	Pack part in sealed box containing bone and wood charcoal or charred leather.
Liquid	Salt bath with amorphous carbon added.
Gas	In retort subjected to carbon monoxide or fuel gases.

NOTE.—For temperatures and heat treatment refer to chart 31.

CYANIDING.—Cyanided parts have a very thin hard surface. This process is cheap and rapid and is usually employed for case hardening unimportant parts, consequently its use is very limited in aircraft work.

Chart 29.—Carburizing heat treatment for steels

SAE steel	Carburizing temperature [1]		Grain refinement temperature core [2]		Hardening temperature case [3]		Tempering or drawing temperature	
	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.
1020	899–927	1, 650–1, 700	857–885	1, 575–1, 625	746–774	1, 375–1, 425	149–204	300–400
2315	871–899	1, 600–1, 650	816–843	1, 500–1, 550	732–760	1, 350–1, 400	149–204	300–400
2512	871–899	1, 600–1, 650	816–843	1, 500–1, 550	704–732	1, 300–1, 350	149–204	300–400
3312	871–899	1, 600–1, 650	774–801. 5	1, 425–1, 475	732–760	1, 350–1, 400	149–204	300–400
4615	899–927	1, 650–1, 700	802–830	1, 475–1, 525	774–802	1, 425–1, 475	149–204	300–400
6115	885–913	1, 625–1, 675	816–871	1, 550–1, 600	788–816	1, 450–1, 500	149–204	300–400

[1] Carburize to desired depth of case, including allowance for grinding, or cool in furnace or air or quench in oil.
[2] Quench in oil. This treatment may be omitted for No. 1020 steel on low stressed parts.
[3] Quench in oil, except SAE 1020 and SAE 6115, which should be quenched in water and brine.

Chart 30.—Heat treatment procedure for structural steel

Steel No.	Normalizing air cool	Annealing	Hardening	Quenching medium 65° F.	Tempering (drawing) temperature for tensil strength (pounds per square inch)				
					100,000	125,000	150,000	180,000	200,000
	° F.	° F.	° F.		° F.	° F.	° F.	° F.	° F.
1020	1, 650–1, 750	1, 600–1, 700	1, 575–1, 675	Water					
x1020	1, 650–1, 750	1, 600–1, 700	1, 575–1, 675	Water					
1025	1, 600–1, 700	1, 575–1, 650	1, 575–1, 675	Water	(1)				
1035	1, 575–1, 650	1, 575–1, 625	1, 525–1, 600	Water	875				
1045	1, 550–1, 600	1, 550–1, 600	1, 475–1, 550	Oil or water	1, 150				
1095	1, 475–1, 550	1, 450–1, 500	1, 425–1, 500	Oil	(2)		1, 100	850	750
2330	1, 475–1, 525	1, 425–1, 475	1, 450–1, 500	Oil or water	1, 100	950	800		
3135	1, 600–1, 650	1, 500–1, 550	1, 475–1, 525	Oil	1, 250	1, 050	900	750	650
3140	1, 600–1, 650	1, 500–1, 550	1, 475–1, 525	Oil	1, 325	1, 075	925	775	700
x4130	1, 600–1, 700	1, 525–1, 575	1, 575–1, 625	Oil [3]	(3)	1, 050	900	700	575
4140	1, 600–1, 650	1, 525–1, 575	1, 525–1, 575	Oil	1, 350	1, 100	1, 025	825	675
4150	1, 550–1, 600	1, 475–1, 525	1, 500–1, 550	Oil		1, 275	1, 175	1, 050	950
x4340	1, 550–1, 625	1, 525–1, 575	1, 475–1, 550	Oil		1, 200	1, 050	950	850
4640	1, 675–1, 700	1, 525–1, 575	1, 500–1, 550	Oil		1, 200	1, 050	750	625
6135	1, 600–1, 700	1, 550–1, 600	1, 575–1, 625	Oil	1, 300	1, 075	950	800	750

6150	1, 600–1, 650	1, 525–1, 575	1, 550–1, 625	Oil	(4) (5)	1, 200	1, 000	900	800
6195	1, 600–1, 650	1, 525–1, 575	1, 500–1, 550	Oil	(6)				
30905		(7) (8)	(9)						
51210	1, 525–1, 575	1, 525–1, 575	1, 775–1, 825 (10)	Oil	1, 200	1, 100	(11)	750	
51335		1, 525–1, 575	1, 775–1, 850	Oil					1, 070
52100	1, 625–1, 700	1, 400–1, 450	1, 525–1, 550	Oil	(6)				
Silica chromium (for springs).			1, 700–1, 725	Oil [12]					

NOTES

[1] Draw at 1,150° F. for tensile strength of 70,000 p. s. i.

[2] For spring temper draw at 800° to 900° F. Rockwell hardness C–40–45.

[3] Bars or forgings may be quenched in water from 1,550°-1,600° F.

[4] Air-cooling from the normalizing temperature will produce a tensile strength of approximately 90,000 p. s. i.

[5] For spring temper draw at 850° to 950° F. Rockwell hardness C–40–45.

[6] Draw at 350° to 450° F. to remove quenching strains. Rockwell hardness C–60–65.

[7] Anneal at 1,600° to 1,700° F. to remove residual stresses due to welding or cold work. May be applied only to steel containing titanium or columbium.

[8] Anneal at 1,900° to 2,100° F. to produce maximum softness and corrosion resistance. Cool in air or quench in water.

[9] Hardened by cold work only.

[10] Lower side of range sheet 0.06 inch and under. Middle of range for sheet and wire 0.125 inch. Upper side of range for forgings.

[11] Not recommended for intermediate tensile strengths because of low impact.

[12] Draw at approximately 800° F. and cool in air for Rockwell hardness of C–50.

Chart 31.—Cyaniding process

Metal	Cyanide bath	Temp. (° F.)	Soak	Quench
Steel parts	Molten sodium or potassium.	1,400° to 1,650°.	30–60 min	Water.

Caution.—Use closed bath; cyanide vapor is poisonous.

Nitriding.—The nitriding process produces a harder case than is obtainable by the carburizing process. Nitriding is limited to steels (Nitralloy) containing small percentages of aluminum, as given in chart 10. The process consists of heating the metal in an airtight circulating air furnace maintaining an anhydrous ammonia atmosphere and a temperature of 950° F. for a period of 48 to 72 hours, followed by air cooling of the metal. Quenching is not required for nitrided parts. The hardness results from the iron nitrides formed in the surface of the metal.

Chart 32.—Color of steel at various temperatures.

Color	Temperature	
	° C.	° F.
Faint red	482	900
Blood red	566	1, 050
Dark cherry	579. 5	1, 075
Medium cherry	677	1, 250
Cherry or full red	746	1, 375
Bright red	843	1, 550
Salmon	899	1, 650
Orange	940. 5	1, 725
Lemon	996	1, 825
Light yellow	1, 079. 5	1, 975
White	1, 204	2, 200
Dazzling white	1, 288	2, 350

Chart 33.—Soaking periods for hardening, normalizing and annealing

Diameter or thickness (inches)	Time of heating to required temperature (approx. hours)	Time of holding (approx hours)
1 and less	¾	½
Over 1 to 2 incl	1¼	½
Over 2 to 3 incl	1¾	¾
Over 3 to 4 incl	2¼	1
Over 4 to 5 incl	2¾	1
Over 5 to 8 incl	3½	1½

Chart 34.—Quenches

Liquid	Cooling rate factor
10 percent solution sodium chloride (brine)	1.00
Water at 65° F	.76
Cottonseed oil	0.15–0.25 depending upon agitation, temperature, viscosity, etc.
Neat's-foot oil	
Fish oil	
Paraffin oil	
Machine oil	

Chart 35.—Tempering temperatures of carbon steel

Oxide color	Metal temperature	
	° C.	° F.
Pale yellow	220	428
Straw	230	446
Golden yellow	243	469
Brown	254	491
Brown (dappled with purple)	266	509
Purple	277	531
Dark blue	288	550
Bright blue	297	567
Pale blue	321	610

SHORE SCLEROSCOPE.—This type hardness tester is designed to enable the operator to determine the hardness reading by carefully watching the rebound, in a graduated glass column, of a diamond-tipped hammer which is dropped from a definite height on to the metal being tested.

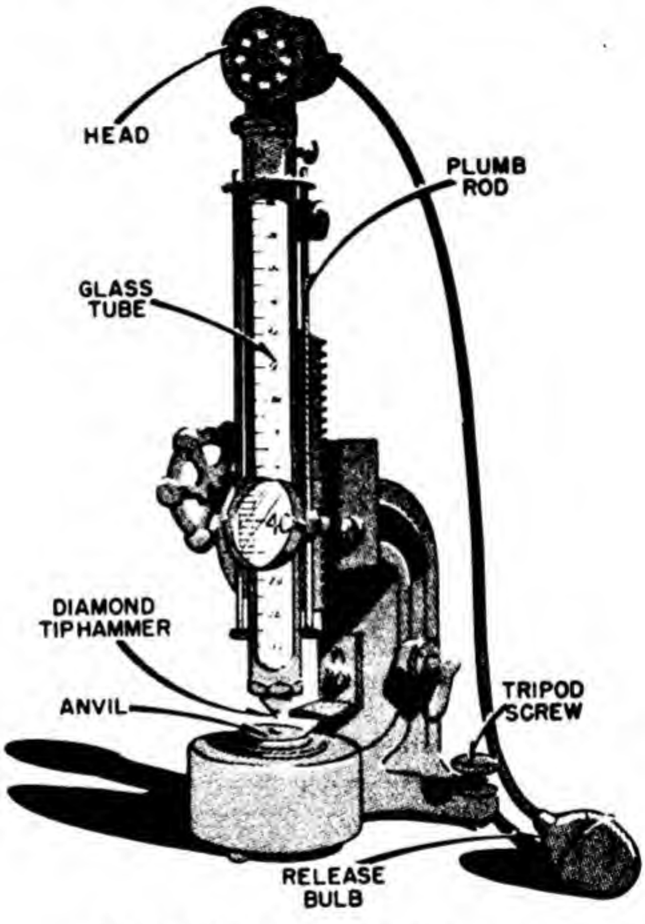


Figure 19.—The shore scleroscope.

Chart 36.—Brinell hardness tester-load and time

Material	Kg.	Time head-held
Steel	3, 000	30 seconds.
Steel (very hard)	500	1 minute.
Aluminum	500	30 seconds.
Brass	500	30 seconds.
Bronze	500	30 seconds.

NOTE.—Size of indentation determined by reading through eyepiece.

Chart 37.—Rockwell hardness tester

Letter (scale)	Penetrator	Major load (kg.)	Dial figures
A	Diamond	60	Black.
B	$\frac{1}{16}$-inch ball	100	Red.
C	Diamond	150	Black.
D	Diamond	100	Black.
E	$\frac{1}{8}$-inch ball	100	Red.
F	$\frac{1}{16}$-inch ball	60	Red.
G	$\frac{1}{16}$-inch ball	150	Red.
H	$\frac{1}{8}$-inch ball	60	Red.
K	$\frac{1}{8}$-inch ball	150	Red.

Chart 38.—Hardness by file reaction

Brinell hardness	Ease with which steel surface can be filed.
100	File bites into surface very easily. Metal is very soft.
200	File readily removes metal with silghtly more pressure. Metal is still quite soft.
300	At 300 Brinell, the metal exhibits its first real resistance to the file.
400	File removes metal with difficulty. Metal is quite hard.
500	File just barely removes metal. Metal is only slightly softer than file.
600	File slides over surface without removing metal. File teeth are dulled.

Chart 39.—Approximate hardness—tensile strength relationship of carbon and low-alloy steels

Rockwell[1]		Vickers diamond pyramid 50 kg load[2]	Brinell[3] 3,000 kg load—10 mm ball		Tensile strength 1,000 p. s. i.
C 150 kg load	B 100 kg load 1/16 ball		Tungsten carbide ball	Steel ball	
67	----------	918	820	717	----------
66	----------	884	796	701	----------
65	----------	852	774	686	----------
64	----------	822	753	671	----------
63	----------	793	732	656	----------
62	----------	765	711	642	----------
61	----------	740	693	628	----------
60	----------	717	675	613	----------
59	----------	694	657	600	----------
58	----------	672	639	584	----------
57	----------	650	621	574	----------
56	121. 3	630	604	561	----------
55	120. 8	611	588	548	----------
54	120. 2	592	571	536	----------
53	119. 6	573	554	524	283
52	119. 1	556	538	512	273
51	118. 5	539	523	500	264
50	117. 9	523	508	488	256
49	117. 4	508	494	476	246
48	116. 8	493	479	464	237
47	116. 2	479	465	453	231
46	115. 6	465	452	442	221
45	115. 0	452	440	430	215
44	114. 4	440	427	419	208
43	113. 8	428	415	408	201
42	113. 3	417	405	398	194
41	112. 7	406	394	387	188
40	112. 1	396	385	377	181
39	111. 5	386	375	367	176
38	110. 9	376	365	357	170
37	110. 4	367	356	347	165
36	109. 7	357	346	337	160
35	109. 1	348	337	327	155
34	108. 5	339	329	318	150
33	107. 8	330	319	309	147
32	107. 1	321	310	301	142

See footnotes at end of table.

Chart 39.—Approximate hardness—tensile strength relationship of carbon and low-alloy steels—Continued

Rockwell [1]		Vickers diamond pyramid 50 kg load [2]	Brinell [3] 3,000 kg load—10 mm ball		Tensile strength 1,000 p. s. i.
C 150 kg load	B 100 kg load 1/16 ball		Tungsten carbide ball	Steel ball	
31	106. 4	312	302	294	139
30	105. 7	304	293	286	136
29	105. 0	296	286	279	132
28	104. 3	288	278	272	129
27	103. 7	281	271	265	126
26	102. 9	274	264	259	123
25	102. 2	267	258	253	120
24	101. 5	261	252	247	118
23	100. 8	255	246	241	115
22	100. 2	250	241	235	112
21	99. 5	245	236	230	110
20	98. 9	240	231	225	107
19	98. 1	235	226	220	104
18	97. 5	231	222	215	103
17	96. 9	227	218	210	102
16	96. 2	223	214	206	100
15	95. 5	219	210	201	99
14	94. 9	215	206	197	97
13	94. 1	211	202	193	95
12	93. 4	207	199	190	93
11	92. 6	203	195	186	91
10	91. 8	199	191	183	90
9	91. 2	196	187	180	89
8	90. 3	192	184	177	88
7	89. 7	189	180	174	87
6	89	186	177	171	85
5	88. 3	183	174	168	84
4	87. 5	179	171	165	83
3	87	177	169	162	82
2	86	173	165	160	81
1	85. 5	171	163	158	80
0	84. 5	167	159	154	78
	83. 2	162	153	150	76
	82	157	148	145	74
	80. 5	153	144	140	72
	79	149	140	136	70

See footnotes at end of table.

CHAPTER 6

METAL FINISHING AND CORROSION PREVENTION

PREPARATION OF SURFACES TO BE TREATED

SAND BLASTING.—Sand blasting consists of forcing abrasives through a nozzle under air pressure against metal surfaces. The general purpose of this process is to clean metal surfaces prior to metallizing and certain plating processes. The work to be cleaned is usually placed in a cabinet into which the blast is directed.

Chart 41.—Sand blasting

Material	Abrasive	Nozzle	Air pressure—p. s. i.
Steel	Sand—steel grit		60–90.
Aluminum	Sand or soft grit	18–24 in work angle 45°.	70 max.

NOTE.—Remove dust with mineral spirits, water, brushing, or blast of air. In no event should sand blasted parts be allowed to contact greasy or dirty hands.

Chart 42.—Sand blasting abrasives

Material	Characteristics
Steel grit	No. 50.
Sand	Pass through No. 24.
Soft grit:	
Hominy grits	Spec. M–H–521.
Clover seed	Mellilotus Indica.
Cracked wheat	Dried and distarched.
Cracked barley	Canadian.
Corn cobs	Ground.
Peanut shells	Ground.
Cocoanut shells	Ground.

VAPOR PRESSURE BLASTING.—Vapor pressure blasting is a process of combining streams of abrasive sand, atomized water or vapor, and an inexpensive rust-inhibiting compound. The streams of sand, vapor, and chemical solution are all under well-balanced pressure and in regulated proportions and are discharged from a nozzle against the surface to be finished. The mixing process reduces wear at the nozzle tip without reducing cutting speed at the point of impact of the cutting sand.

Vapor pressure blasting has several advantages over conventional sand blasting. The vapor pressure blasting process will polish surfaces when tolerances are no more than 0.0001-inch; it will reach edges and corners that are almost impossible to clean, deburr, or polish by other means; and the peening has the effect of cold working the surface of the metal improving tensile strength from 5 percent to 10 percent.

The vapor pressure process of blasting is recommended for removal of heat treat scale, preparation for electroplating and electropolishing, cleaning rust, carbon, and other deposits from parts, removing grinding lines and fine machine lines, finishing threaded parts, honing of cutting tools, cleaning preparatory to welding, and removal of welding flux and weld spatter.

METALLIZING.—Metallizing is a process of spraying metal on parts for the purpose of corrosion protection or the rebuilding of worn metal parts.

In surface preparation sand blasting and rough threading provides a bonding surface.

Equipment:

- Oxygen regulator—two stages
- Acetylene regulator—two stages
- Air regulator—single stage
- Water and oil extractor—for air line
- Proper sand blasting equipment
- Abrasive—36 mesh, jagged or angular silica sand

SAND BLASTING.—Remove scale from metal holding nozzle at a 30–45 degree angle to and 6 to 8 inches from work. Final sandblasting is accomplished by holding nozzle perpendicular to and 6 to 8 inches from work.

APPLICATION.—Hold gun 4 to 6 inches from and perpendicular to the surface being sprayed. Overlap each pass of the gun ⅓ the pass width. If two or more coats are applied, each coat must be at right angles to the previous coat.

THICKNESS OF COATINGS.—Aluminum: 0.022-inch to 0.004-inch in thickness. Steel: thicker coatings permissible.

POLISHING AND BUFFING.—Polishing and smoothing operations precede plating and are accomplished by an assortment of wheels and abrasives. Parts should be polished with coarse abrasive #150 followed by #200. These abrasives are bonded to a cloth wheel with glue. Final polishing is done on a cotton wheel using a recommended finishing compound.

Buffing, to bring about a highly polished surface, is performed on cotton wheels using such abrasives as tripoli compound.

PLATING.—Plating is a process whereby a very thin layer of metal, such as copper, cadmium, gold, sliver, chromium, etc., is deposited by an electro-chemical process upon parts to prevent corrosion or excessive wear to the base metal. However, some metals are plated with nickel chromium, silver, gold, etc., for purely decorative purposes.

SAFETY NOTE.—Before carrying on plating activities, contact the Medical Department for advice as to first-aid treatment for acid burns and other accidents common to a plating shop. In all circumstances, be familiar with first-aid treatments.

Chart 43.—Typical plating cleaning sequence (chromium) for ferrous and nonferrous metals

FERROUS (STEEL)

Sequence of process	Solution	Electrolyte
Degrease	*Trichloroethylene	
Rinse	Cold water	
Buff (suitable buffing wheel).		
Clean		Cleaner—sodium carbonate, 4 oz. Trisodium phosphate, 4 oz. Cathode is the work. Current density 50 amp. per sq. ft. for 3–5 min. Solution temp. 194° F.
Rinse	Warm water	
Dip	Few seconds 10% sulphuric acid at 122° F.	
Rinse	Water—room temp. Scrub with pumice stone in water to etch.	
Dip (few sec.)	Sulphuric or chromic acid.	
Rinse	Warm water	
Plate		Chromium plating solution.
Rinse	Hot water	

**Caution*—Trichloroethylene fumes are poisonous. It should be used in well ventilated areas only.

Chart 43.—Typical plating cleaning sequence (chromium) for ferrous and non-ferrous metals—Continued

NON-FERROUS (BRASS OR COPPER)

Sequence of process	Solution	Electrolyte
Degrease	Trichloroethylene	
Rinse	Cold water	
Buff (suitable buffing wheel).		Cleaner—sodium carbonate, 4 oz. per gal. Trisodium phosphate, 4 oz. per gal. Sodium cyanide, ½ oz. per gal.
Rinse	Warm water	
Dip	By volume sulphuric acid, 44%, Nitric acid, 7%, hydrochloric acid, 0.2%, Water, 49%.	
Rinse	Warm water	
Plate		Chromium plating solution.
Rinse	Hot water	

**Caution*—Trichloroethylene fumes are poisonous. It should be used in well ventilated areas only.

CADMIUM PLATING.—Application: Plated directly to the metal with a minimum thickness of 0.0003 inch. Threads require a minimum of 0.0002 inch.

Chart 44.—Cadmium plating solution

Composition	Tank plating (ounces per gallon)	Barrel plating (ounces per gallon)
Sodium cyanide	9–12	10–20
Cadmium oxide	3–4	4–7
Caustic soda	1–2	1–2
Brightener (as required)		

Chart 45.—Brightener for cadmium plating solution

Composition	Ounces per gallon
Hide glue	1/16
Molasses	1/4

Chart 46.—Time and current density required for cadmium plating

Thickness of cadmium deposit	Plating time and amperes per sq. ft.			
	10 min. (amps. per sq. ft.)	20 min. (amps. per sq. ft.)	30 min. (amps. per sq. ft.)	40 min. (amps. per sq. ft.)
0.0001	5. 9	3. 0	2. 0	1. 5
0.0002	11. 8	5. 9	3. 9	3. 0
0.0003	17. 7	8. 9	6. 0	4. 5
0.0005	29. 5	14. 8	9. 8	7. 4
0.00075	44. 2	22. 1	14. 7	11. 0
0.0010	59. 0	29. 5	19. 8	14. 8

CHROMIUM PLATING.—Chromium may be plated directly on to steel to finished dimensions or plated and ground to the desired dimensions.

Chart 47.—Cleaning solution for parts to be chromium plated

Solution	Ounces per gallon
Sodium carbonate (soda ash, Na_2CO_3)	4
Trisodium phosphate (Na_3PO_4)	4

To clean steel add one-half ounce of sodium hydroxide (NaO_4) per gallon to the stock solution in chart 47. To clean copper or brass add one-half ounce of sodium cyanide (NaCN) to the stock solution.

Chart 48.—Chromium plating solution

Composition	Ounces per gallon
Chromic acid	33–37
Sulphuric acid	0. 33–0. 37

Chart 49.—Temperature, time and current density required for chromium

Temperature of plating (°F.)	Bath (°C.)	Plating time and amperes per sq. ft. for 0.0001 in plate	
		Amperes per sq. ft.	Time (min.)
113	45	100–40	25
122	50	150–60	15
131	55	200–80	11
140	60	250–100	7

Copper plating.—Copper is deposited on surfaces to prevent corrosion and often to form a base for further chrome and nickel plating.

Solution for copper plating.—To make a gallon of solution, mix 3 to 8 ounces of Rochelle salt with from 4 to 7 ounces of sodium cyanide and complete the mixture by adding sodium carbonate (2 to 8 ounces) and 3 to 6 ounces of copper cyanide.

COPPER PLATING PROCESS.—The amperes per square foot (current density) should range between 20 and 60, or have the voltage ranging between 2 and 3 volts. Copper anodes which have been rolled after annealing should be used. The preferred temperature of this solution while plating is 140° F.

NICKEL PLATING.—Nickel may be plated on any metal surface (not stainless or chrome) either for decorative, corrosion prevention or chrome undercoating purposes.

SOLUTION FOR NICKEL PLATING.—A gallon of nickel plating solution, as recommended by some Naval establishments, should contain nickel chloride in the amount of 7 ounces, with a nickel sulfate content of 40 ounces, plus 5 ounces of boric acid.

NICKEL PLATING PROCESS.—The amperes per square foot (current density) should be maintained between 50 and 80. A 140° F. solution temperature should be maintained while metal or parts are being plated.

SILVER PLATING.—Engine parts (bearing surfaces) are often silver plated for better operation. Silver is also used for decorative and corrosion preventive purposes.

SOLUTION FOR SILVER PLATING.—A recommended silver plating solution contains, per gallon, 2½ ounces of potassium cyanide and 30 troy ounces of silver cyanide. In addition to the silver cyanide and the potassium cyanide, the solution should contain potassium carbonate (8 ounces) and also 3 troy ounces of metallic silver per gallon.

SILVER STRIKE PLATING.—The primary purpose of a silver strike is to get silver coverage of the metal prior to final plating. The tank containing the plating solution should be equipped with silver (pure) anodes. The amperage per square foot may range from 15 to 25, or a voltage of 6 volts may be used. Silver strike plating is carried on with the solution at room temperature.

SOLUTION FOR SILVER STRIKE.—A typical silver strike solution contains, per gallon, 10 ounces of sodium cyanide, a quantity of silver cyanide (0.25 troy ounce), and $\frac{2}{10}$ of a troy ounce of metallic silver.

SILVER PLATING PROCESS.—The procedure is the same as silver strike plating.

STRIPPING SOLUTIONS

Often it becomes necessary to strip old or defective plating from parts. The following paragraphs deal with the more common stripping processes.

STRIPPING CADMIUM.—Cadmium may be stripped from steel, copper or brass by immersing the part in a recommended solution composed of water (one-half pint), and a gallon of hydrochloric acid plus antimony trioxide in small amounts (2 ounces). The solution at time of immersion should be at room temperature.

STRIPPING CHROMIUM.—Chromium may be stripped from nickel or steel by putting the part in a solution, containing water and six ounces of sodium hydroxide per gallon of solution. This process requires that the current (6 volts) be reversed and for better results the temperature of the solution should be at room temperature. If chromium is to be removed from nickel, brass or copper, use a solution consisting of water with 1 pint of concentrated hydrochloric acid per gallon of solution. Maintain a solution temperature of 125° F. while the metal is being stripped.

STRIPPING COPPER.—To strip copper from a nonferrous metal, the metal is soaked 5 minutes in a solution (room temperature) each gallon of which contains two ounces of sulphur plus 28 ounces of sodium sulphide with water making up the remaining part of each gallon.

NOTE.—The sulphur may be dissolved in the solution by boiling.

Immersion creates loose sulphides, which may be removed with a brush; then the metal should be rinsed off and dipped in a 10 percent solution of sodium cyanide. The metal should again be brushed after the cyanide dip.

STRIPPING NICKEL.—Nickel may be stripped from copper, brass or steel if subjected to a solution (room temperature) containing a pint of water and a gallon of sulphuric acid along with an ounce of either molasses or glycerine. This process requires that the current (6 volts) be reversed. The plating tank should be equipped with lead cathodes.

STRIPPING SILVER.—A recommended solution for stripping

silver from nickel, silver or brass contains sulphuric acid and nitric acid in proportions of 19 to 1 (by volume). The temperature of the bath while parts are being stripped should be 180° F.

CORROSION PREVENTION

The prevention of corrosion is of primary importance in aircraft construction. A short listing of corrosion preventive measures, excluding dissimilar metal corrosion and plating processes, is as follows:

Control cables	Paralketone Type I.
Gas tanks (exterior surfaces)	Zinc chromate primer (2 coats).
Aluminum 17S–24S (exterior surfaces)	Zinc chromate primer (2 coats).
Street ends and similar parts of seaplanes	Paralketone Type I.
Float compartments	Potassium chromate.
Steel (surface pretreatment)	Chromic acid.
Aluminum (surface pretreatment)	Chromic acid.

ANODIZING

Anodizing is an electro-chemical process whereby an aluminum oxide film is formed on aluminum (5 percent maximum copper) surfaces. The purpose of such a treatment is twofold. First, the surface of the metal is rendered more corrosion resisting. Second, it provides a satisfactory base for paint, if the surface is to be painted.

Electrolyte:

Chromic acid	5–10 percent by weight.
Water	Remainder.
Maximum chloride in water	0.02 percent NaCl per liter.
Maximum sulfate in water	0.05 percent H_2SO_4 per liter.

Electrolyte temperature.—95± ° F.

PREPARATION OF PARTS.—Remove all grease, oil, paint, etc. Recommended cleaners are solvent, thinner, cleaner or free-rinsing soap. Salt bath treated parts must be entirely free of salt, which is accomplished by washing parts in running water immediately following heat treatment.

VOLTAGE AND TIME.—Apply a small potential across tank. Increase voltage 5–10 volts per minute until 40±1 volt is

reached. Hold the load for at least 30 minutes at 40 volts.

TREATMENT AFTER ANODIZING.—Wash part in water at 149 to 185° F.

CHROMIC ACID SOLUTION

A solution of 5 percent chromic acid dissolved in water may be applied to aluminum, aluminum alloy or steel with a brush or a soft cloth.

Caution.—Solution that penetrates faying surfaces is detrimental.

After solution has remained on the surface 5 to 10 minutes, remove by lightly scrubbing area with hot water and bristle brush.

CORROSION PREVENTIVE COMPOUND—PARALKETONE TYPE I

Paralketone is not to be considered as a paint substitute, although its use is permitted as an emergency measure. Paralketone is a corrosion and rust preventive for ferrous and nonferrous parts exposed to the weather.

APPLICATION.—Application is accomplished by brushing, spraying or dipping methods, maintaining the solution temperature between 40° and 95° F.

Caution.—Surface must be clean even to fingerprints. Do not heat above 95° F. Flash point (100° F). Do not use an open flame to heat.

CORROSION PROTECTION OF MAGNESIUM ALLOYS

PREPARATION OF PARTS.—All traces of oil, grease, welding flux or paint must be removed. Organic solvents are used to remove oil or grease providing they are of a type that will not attack the metal. Sanding and wire brushing are recommended methods for oxide film removal. Paints may be removed from surface by paint remover (caustic), sanding or scraping.

Caution.—Do not sandblast thin sections.

Chart 50.—Alkaline cleaner—prior to chemical treatment

Material	Amount
Sodium carbonate (soda ash)	4 oz.
Tri-sodium phosphate	4 oz.
Easily soluble soaps or welding agent	0.1 oz.
Water to make	1 gal.

If parts still have surface contamination, pickle in solution given in either chart 50, 51, or 52.

Chart 51.—Nitric-Sulphuric acid pickle

Material	Parts by volume
Water	90
Nitric acid (concentrated)	8
Sulphuric acid (concentrated)	2

NOTE.—In mixing water with concentrated acids always pour the acid into the water. Reversing this procedure will result in release of highly toxic fumes and uncontrolled sputtering of acid droplets.

The nitric-sulphuric acid pickle operation should be completed at room temperature. The metal parts should be given a 10-second dip and then a rinse. Blasted parts should remain in solution until 0.002 inch is removed; round stock until diameter is decreased 0.004 inch.

Chart 52.—Hydrofluoric acid pickle

Material	Parts by volume
Hydrofluoric acid	1
Water	2

Immerse parts for a period of 5 minutes.

Caution.—Hydrofluoric acid fumes are highly toxic and should be used with extreme care under enclosed hoods only.

Chart 53.—Chromic acid pickle

Material	Amount
Chromic acid	1.5 lbs.
Water (to make)	1 gal.

The above operation takes place at room temperature or 194–212° F. Immersion time is 1 to 15 minutes, depending upon temperature of bath and part conditions.

CLEANING WROUGHT MATERIALS.—As outlined and discussed in first paragraph, "Preparation of Parts."

CLEANING SAND CASTINGS.—Clean new castings by blasting and pickling as outlined in charts 50, 51, and 54.

CLEANING RE-TREATED CASTINGS.—Oils and paints are removed as discussed in first paragraph "Preparation of Parts" and chart 50. Any corrosion that exists may be removed in a chromic acid pickle.

PROCEDURE FOR APPLICATION OF PROTECTIVE FINISHES.—Sheet and unmachined materials are first pickled.

Chart 54.—Chrome-pickle solution

Material	Quantity ±2 percent
Sodium dichromate	1.5 pounds.
Nitric acid	1.5 pints.
Water (to make)	1 gallon.
ALTERNATE—CHROME PICKLE SOLUTION	
Chromium trioxide	1 pound.
Nitric acid	0.9 pint.
Water (to make)	1 gallon.

OPERATION

1. Solution temperature 70°–90° F.
2. Etch by immersion (½–2 minutes) and agitation.
3. Remove and expose to air (5 seconds).
4. Wash thoroughly in running water (cold).
5. Give hot water dip.

SEALING CHROME PICKLE.—Dry part and immerse in a solution consisting of a 10 to 20 percent dichromate, plus 0.25 percent magnesium or calcium fluoride (by weight), for 3 minutes. The required temperature of such a solution is at boiling point. After immersion, rinse parts in running water (cold) followed by a hot water dip. The surface is ready for paint after it is thoroughly dry.

GALVANIC ANODIZED TREATMENT.—In a water solution at room temperature, which contains (by weight) 15 to 20 percent hydrofluoric acid, immerse parts for 5 minutes. Remove and thoroughly wash in running water (cold). These parts are ready to be galvanically anodized.

Chart 55.—Anodizing bath

Material	Quantity ± 2 percent
Ammonia sulfate	4 ounces.
Sodium dichromate	4 ounces.
Ammonia	⅓ fluid ounce.
Water (to make)	1 gallon.

OPERATION

1. Use iron or steel cathode plates, if nonmetallic tank.
2. Connect parts (electrically) to cathode plates.

Caution.—Allow only contact by connection.

3. Current density: Min. 2, max. 10 amps. per sq. ft.
4. Length of process: Until a black uniform coat is produced. However, the time is never less than 70 amp. minutes per sq. ft.

PASSIVATING

The exhaust system collector rings and collector ring supports, stacks, preheaters, etc., which are made from heat and corrosion resisting alloys, must be passivated after fabrication and heat treatment.

PREPARATION OF METAL.—There are two alternatives, either sand blast and then passivate or sand blast and polish followed by passivation. The necessity of polishing is determined by the finish requirements.

PROCEDURE FOR PASSIVATING.—Immerse in solution given below, followed by rinsing.

Chart 56.—Passivating solution, temperature and time

Solution	Temperature ° F.	Time (minutes)
20 percent nitric acid (by volume)	125–135	20–40
80 percent water		

POTASSIUM CHROMATE CRYSTALS

To prevent corrosion, a special container (aluminum) filled with potassium chromate is placed in low areas of each hull and float compartment as well as fuel tank sumps.

ZINC CHROMATE PRIMER

BRUSHING.—Thin (1 part primer thinned with 1 to 1½ parts thinner) and quickly spread with brush (4″). Coated areas should never be reworked.

DIPPING.—Add thinner 2½ to 3 parts, to 1 part primer. Parts are withdrawn from solution at a rate of speed which will permit excess solution to properly drain.

Chart 57.—Spray application

Material	Air pressure	Gun positions	Coat color
Add 2–2½ parts of thinner* to 1 part of material.	15–40 p. s. i	Close	Greenish yellow.

*Thinner—Toluene substitute—AN-T-8.

DRYING TIME.—Films of normal thickness may be handled in 5 minutes.

USE AS A SEALER.—Insignia and marking lacquers may be applied over oil enamels, if first sealed with zinc chromate. Drying time 6 hours.

INSULATION OF DISSIMILAR METALS

Aluminum alloys may be grouped into two groups, as given in chart 58. The metals in group I are similar one to

another. The metals in group II are also similar to each other. However, any alloy in group I is regarded as dissimilar to any alloy in group II.

Chart 58.—Similar and dissimilar metals

Group I	Group II	Group I	Group II
2S	195.	61S	14S.
3S	17S.	43	25S.
52S	24S.	355	
53S	A17S.	Alclad alloys	

Chart 59.—Electrical potential difference of metals

Smallest electrical potential difference exists between any two metals appearing together. (Example: tin and copper.)	Magnesium; zinc; aluminum; cadmium; non-corrosion-resisting steel; tin; copper; nickel; stainless steel.	Electrical potential difference increases as metals being "paired" are farther apart as listed. (Example: stainless and magnesium.)

CHAPTER 7
AIRCRAFT FASTENERS
COWL FASTENERS

There are at least three cowl fasteners in common use today, the Camloc, DZus, and Airloc, as well as several other qualified fasteners such as the Shakeproof, Lion, and Scovill-Lahodiakin.

While all fasteners perform essentially the same function, they have differing characteristics. For a general description of a cowl fastener we will describe the Camloc.

Camloc fasteners are available in two sizes—$\frac{3}{8}$-inch and $\frac{3}{16}$-inch stud head. The two sizes differ in the number of parts, that is, the $\frac{3}{8}$-inch size has three parts—receptacle, grommet, and stud assembly (as shown in fig. 20)—while the smaller sizes have only two parts—receptacle and stud assembly.

The receptacle is of two types, a fixed and a floating type. The fixed receptacle is used very little at present and for repair or replacement should be replaced with the floating type. The receptacle consists of an aluminum alloy forging mounted in a stamped sheet metal base in which it has room for approximately $\frac{1}{8}$-inch float in the plane of the cowling sheet. This assembly is riveted to the cowling supports or cowling.

The grommet is a flanged ring made to fit into a dimple in external cowling.

The stud assembly consists of a stud, cross pin, spring, and spring cup. It is permanently assembled at the factory and

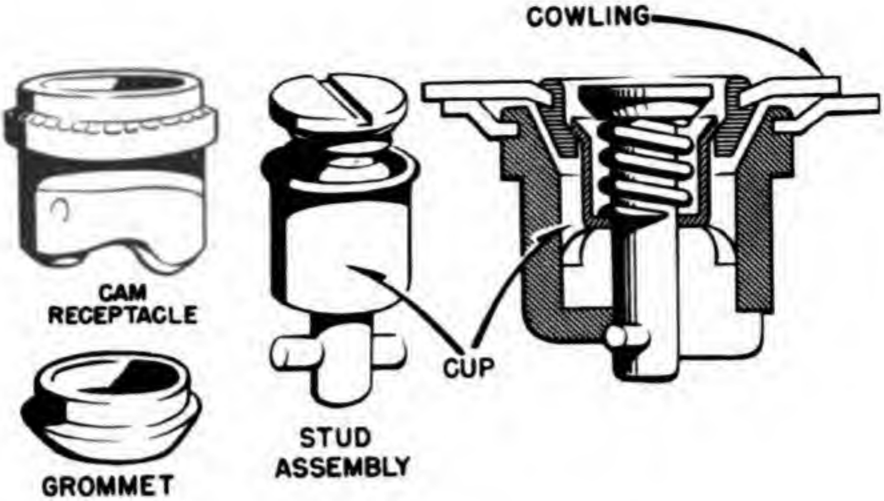


Figure 20.—Camloc parts.

should never be disassembled. The assembly is so designed that it can be quickly inserted into the grommet by compressing the spring. Once installed in the grommet, the stud assembly cannot be removed until the spring is again compressed.

When it becomes necessary to replace the Camloc receptacle, it can be done by removing the rivets, installing a new receptacle, and by riveting it into place. The grommet may be removed with pliers or by enlarging the dimple by pressure from the top. When replacing the stud assembly, it is convenient to use Camloc pliers No. 4P4. Compress the spring of the assembly with the pliers and enter the stud through the grommet.

Selection of size.—The combined thickness of all sheets to be fastened together is the basis for selection of stud length as indicated by chart 60 or 61. These charts also show how sheet thickness, in which receptacle or grommet is to be installed, governs its selection.

DILL LOK-SKRUS AND LOK-RIVETS

Dill fasteners.—Dill fasteners, available with flush, flat or countersunk heads, screw or rivet type designed to be used when blind fastening is required. The difference between the two, as illustrated in figure 21, is mainly in that the screw type is tapped and the rivet type is not.

Chart 60.—Selection chart for large size Camlocs.

Name of part	Camloc part No.	Panel thickness	Total grip thickness	Stud length
Stud	2500 A-1	0. 020-0. 029	0. 070-0. 099	0. 351
Stud	2500 A-2	. 020- . 029	. 100- . 129	. 381
Stud	2500 A-3	. 020- . 029	. 130- . 159	. 411
Stud	2500 A-4	. 020- . 029	. 160- . 189	. 441
Stud	2500 B-1	. 030- . 039	. 070- . 099	. 351
Stud	2500 B-2	. 030- . 039	. 100- . 129	. 381
Stud	2500 B-3	. 030- . 039	. 130- . 159	. 411
Stud	2500 B-4	. 030- . 039	. 160- . 189	. 441
Stud	2500 C-1	. 040- . 049	. 070- . 099	. 351
Stud	2500 C-2	. 040- . 049	. 100- . 129	. 381
Stud	2500 C-3	. 040- . 049	. 130- . 159	. 411
Stud	2500 C-4	. 040- . 049	. 160- . 189	. 441
Stud	2500 C-5	. 040- . 049	. 190- . 219	. 471
Stud	2500 D-2	. 050- . 059	. 100- . 129	. 381
Stud	2500 D-3	. 050- . 059	. 130- . 159	. 411
Stud	2500 D-4	. 050- . 059	. 160- . 189	. 441
Stud	2500 D-5	. 050- . 059	. 190- . 219	. 471
Stud	2500 E-2	. 060- . 069	. 100- . 129	. 381
Stud	2500 E-4	. 060- . 069	. 160- . 189	. 441
Stud	2500 E-5	. 060- . 069	. 190- . 219	. 471

Chart 61.—Selection chart for large size Camlocs

Name of part	Camloc part no.	Total grip thickness	Stud length
Receptacles	–494	Inner 0.050 to 0.070	
Receptacles	–494	Inner 0.050 to 0.070	
Grommet	4002–B	Outer 0.025 to 0.031	
Grommet	4002–C	Outer 0.032 to 0.050	
Stud assembly	4002–1	(Total) 0.051 to 0.080	0.383
Stud assembly	4002–2	(Total) 0.081 to 0.110	.413
Stud assembly	4002–3	(Total) 0.111 to 0.140	.443
Stud assembly	4002–4	(Total) 0.141 to 0.170	.473
Stud assembly	4002–5	(Total) 0.171 to 0.200	.503
Stud assembly	4002–6	(Total) 0.201 to 0.230	.533
Stud assembly	4002–7	(Total) 0.231 to 0.260	.563
Stud assembly	4002–8	(Total) 0.261 to 0.290	.593
Stud assembly	4002–9	(Total) 0.291 to 0.320	.623
Stud assembly	4002–10	(Total) 0.321 to 0.350	.653
Stud assembly	4002–11	(Total) 0.351 to 0.380	.683
Stud assembly	4002–12	(Total) 0.381 to 0.410	.713
Stud assembly	4002–13	(Total) 0.411 to 0.440	.743
Stud assembly	4002–14	(Total) 0.441 to 0.470	.773
Stud assembly	4002–15	(Total) 0.471 to 0.500	.803
Stud assembly	4002–16	(Total) 0.501 to 0.530	.833
Stud assembly	4002–17	(Total) 0.531 to 0.560	.863

Stud assembly	4002–18	(Total) 0.561 to 0.590	. 893
Stud assembly	4002–19	(Total) 0.591 to 0.620	. 923
Stud assembly	4002–20	(Total) 0.621 to 0.650	. 953
Stud assembly	4002–21	(Total) 0.651 to 0.680	. 983
Stud assembly	4002–22	(Total) 0.681 to 0.710	1. 013
Stud assembly	4002–23	(Total) 0.711 to 0.740	1. 043
Stud assembly	4002–24	(Total) 0.741 to 0.770	1. 073
Stud assembly	4002–25	(Total) 0.771 to 0.800	1. 103

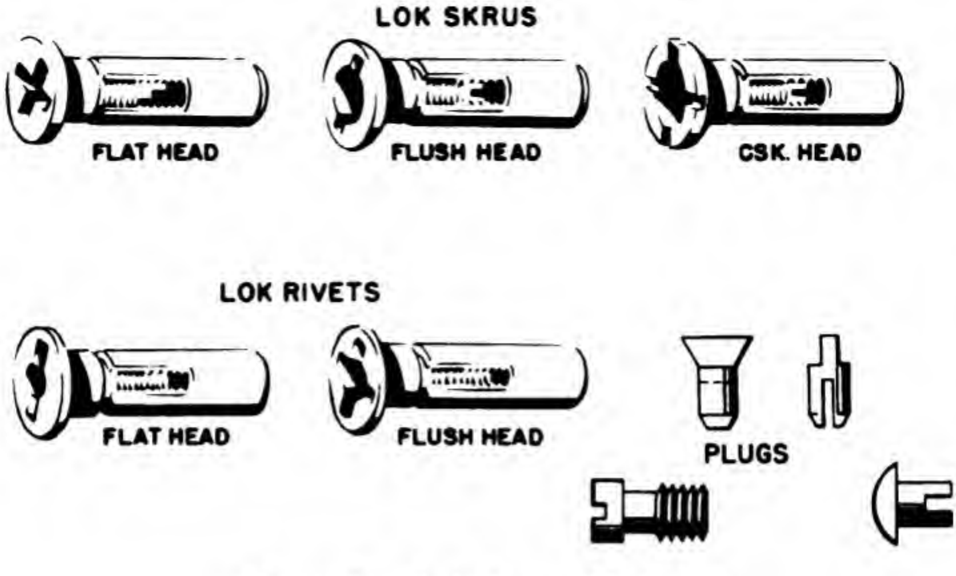


Figure 21.—Lok-skrus and Lok-rivets.

SIZES.—Lok-skrus, either steel or aluminum, come in diameters of 0.297, 0.234, and 0.265, with a variety of lengths for each diameter. Lok-rivets come in diameters of 0.265, 0.234, and 0.187, with flat, flush, or countersunk heads. A special tool is needed for proper installation of this type fastener.

HEX HEAD BOLTS

Bolts are intended primarily as structural fasteners. There are various bolts which are used depending on the application. Hex head bolts are used in either shear or tension with certain AN limitations. They are identified by head markings. Hexagon steel bolts are heat treated to 125,000 p. s. i. while internal wrenching bolts (MA 20004 series) are heat treated to 160,000 p. s. i.

Chart 62.—Hex head bolt identification

Metal	Bolt head marking
Aluminum alloy	Double dash (raised or depressed).
Steel (nickel steel)	Raised X.
Corrosion resisting steel	Raised dash.
Close tolerance (steel or aluminum) bolts.	Triangle raised or depressed (in addition to above material designation).

PRECAUTIONS IN USE.—Aluminum alloy bolts under ¼ inch and steel bolts under 10/32 are not to be installed as fastening devices in primary structures. Aircraft bolts cannot be substituted by commercial machine screws. Properly installed bolts will not have more than 1½ threads left within the hole.

Close tolerance bolts should be used in special, close tolerance holes which have been reamed to size. These items are being used extensively at present.

COTTER PINS

Cotter pins should be installed as indicated in figure 22. A good installation is characterized by snug fit. Severe bending is detrimental.

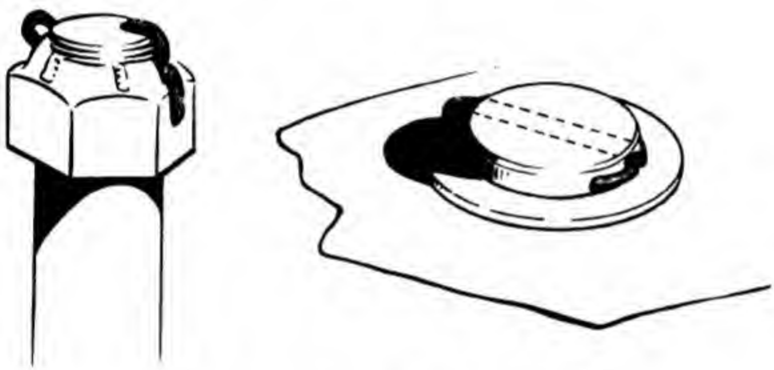


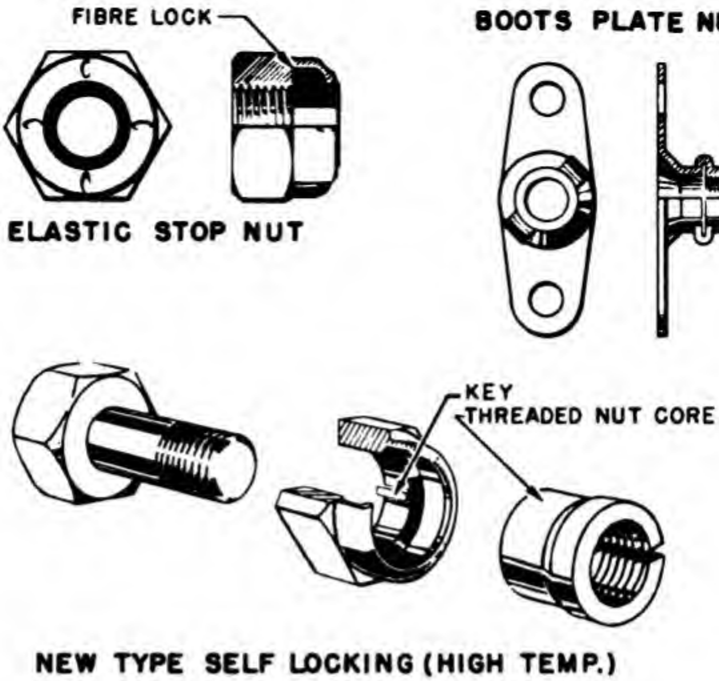
Figure 22.—Cotter pin installation.

Caution—When clipping excess length from cotter pins protect eyes from flying pieces.

SELF-LOCKING NUTS AND NUT PLATES

Self-locking nuts (fig. 23) and nut plates are essentially a nut with a special insert, which is tapped as it engages the threads of the bolt during the tightening process. Such an insert may be metal or fiber.

To insure the self-locking efficiency, care must be exercised to prevent lubricants from contacting the elastic portion of the nut. The correct bolt length is indicated when a full thread or chamfered edge of bolt appears above the insert.



Figue 23.—Self locking nut.

WASHERS

The types of washers used in aircraft structure are: plain washers, lock washers (fig. 24), and special washers.

Plain washers are widely used under AN hex nuts to provide a smooth bearing surface, to act as a shim in obtaining

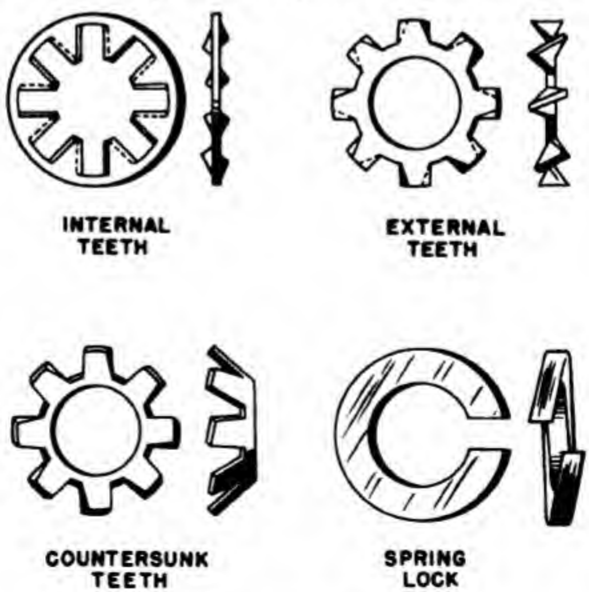


Figure 24.—Lock washers.

the correct relationship between the threads of the bolt and the nut, and to adjust the position of castellated nuts with respect to drilled cotter pin holes in bolts. Plain washers should be used under lock washers to prevent damage to the surface of delicate materials.

Lock washers are used with machine screws or bolts whenever the self-locking or castellated type of nut is not applicable. Sufficient friction is provided by the spring action of the washer to prevent loosening of the nut from vibration.

Lock washers *shall not* be used under the following conditions:

1. As fastenings to primary or secondary structures.
2. As fastenings for super structure or accessories where failure might result in danger or damage to the airplane or personnel.
3. Where failure would permit the opening of a joint to airflow.
4. Where the screw is subject to frequent removal.
5. Where the washers are subject to corrosive conditions.
6. Where the washers are used on exposed surfaces subject to airflow.
7. Where the washers are against soft material, such as aluminum or magnesium, without a plain washer and underneath to prevent gouging on the surface.

Special washers include ball-sockets and seat washers, taper pin washers, and washers for internal wrenching nuts and bolts.

RIVETS

Universal-head rivets.—Where replacement of rivets is necessary, all protruding head rivets (round-head, flat-head, and brazier-head) can be replaced by AN-470 universal-head rivets. However, AN-456 rivets may be used as replacement for brazier-head rivets, and AN-430 rivets may be used as replacement for round-head and flat-head rivets until current stocks of AN-456 and AN-430 rivets are exhausted. In the future, only AN-470 rivets will be stocked for repair purposes, as it is considered a suitable replacement for all protruding head rivets.

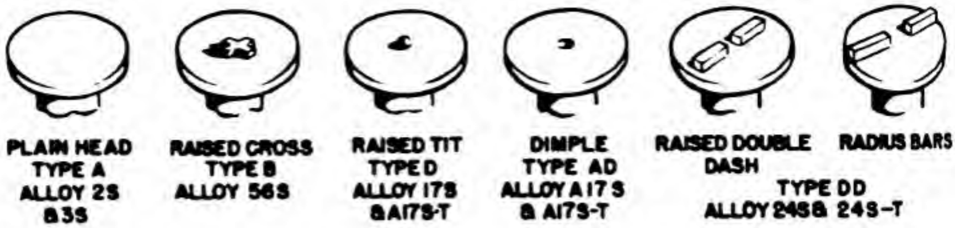


Figure 25.—Rivet identification markings.

AN RIVET CODE.—A system of letters and numbers has been adopted by the Army and Navy to standardize the specifications of aircraft rivets. As an example let's take the code AN-430-AD5-12 and see what it means. The letters AN indicate Army-Navy specifications. The three digits 430 state the head shape of the rivet. The letters AD designate the alloy from which the rivet is made. The numeral 5 following AD, indicates the diameter of the rivet in 32nds of an inch. The 12 indicates the length in inches. A complete break down of the code is given below:

```
AN  430  AD  5  12
|    |    |  |  |__Length in 16ths of an inch.
|    |    |  |_____Diameter in 32nds of an inch.
|    |    |________Material code as shown above
|    |               (A17ST).
|    |_____________Head style.
|__________________Army-Navy specification.
```

The various head shapes indicated by the first two numbers of the code are as follows:

AN-430	Round head.
AN-435	
AN-442	Flat head.
AN-441	
AN-425	Countersunk head.
AN-420	
AN-426	Countersunk head.
100°	
AN-455	Brazier head.
AN-456	

Chart 63.—AN Rivet identification

Head marking	Material	AN standard rivet material									AN material code	Condition	Heat treat before using
		420	425	426	430	435	441	442	455	456			
Plain	2S		X		X			X			A	As fabricated	No.
Raised cross	56S			X	X						B	As fabricated	No.
Dimpled	A17ST		X	X	X			X	X	X	AD	(T) Heat treated	No.
Raised tit	17ST		X	X	X			X	X	X	D	(T) Heat treated	Yes.
Raised tit	17ST-A		X	X	X			X	X	X	AD	(T) Heat treated	No.
Raised double dash	24ST		X	X	X			X	X		DD	(T) Heat treated	Yes.
Plain	Iron (mild steel).	X				X	X				None	As fabricated	No.
Plain	Copper	X				X	X				C	As fabricated	No.

Replacements shall be made with rivets of the same size and strength, if available. If the rivet hole has become enlarged, deformed, or otherwise damaged, the next larger size rivet shall be used after reworking the hole. Replacement shall not be made with rivets of lower strength material unless they are of a size larger than those removed. For example, a rivet made of 24ST aluminum alloy shall not be replaced by one made from 17ST aluminum alloy unless the 17ST rivet is of the next larger size. When replacements with larger size rivets are made, caution must be used with regard to maintaining proper edge distance, which should not be less than 2.0 times the rivet diameter. Edge distance is defined as the distance from the center of a rivet hold to the nearest edge.

17ST aluminum alloy rivets are being used in Naval aircraft as two different type rivets, with each type having its own physical properties. One is known as the 17ST soft driven rivet because after heat treatment it is quenched and kept refrigerated in the *as quenched* condition until used and driven. The design shear strength for this rivet is 34,000 p. s. i. The other rivet, known as 17ST–DH (formerly known as 17ST–A), is aged at room temperature 4 days or longer after being quenched, and it is then driven. The dash DH (–DH) is the code signifying that this rivet is driven hard. The design shear strength for this type rivet is 38,000 p. s. i. Both 17ST (soft-driven) and 17ST–DH rivets have the same head markings (raised teat). *Since it will be impossible to distinguish between 17ST (soft-driven) and 17ST–DH rivets after they have been driven, all 17ST rivets as originally installed shall be treated as 17ST–DH rivets by repair activities and shall be replaced either by the same size 17ST–DH rivet, or by 17ST (soft-driven) rivets of the next larger size.* However, overhaul activities may use available aircraft contractor's blueprints and specifications to identify the type and size rivets required for replacement of rivets originally installed.

A17ST aluminum alloy rivets (not to be confused with either of the above types of 17ST rivets) may be used for general repair purposes including repairs to hulls and

floats, regardless of whether the parts are made of clad material. Only 56S aluminum alloy rivets shall be used to rivet magnesium alloys. Where rivets other than aluminum alloy rivets are to be replaced, replacement shall be made with the same type of rivet as originally installed.

RIVET HEAD SHAPES.—Rivets used may be selected on basis of head shape as well as alloy. As a guide to such selection refer to chart 64.

Chart 64.—Rivet head shapes and uses

Head shape	Use
Countersunk 100°	Surfaces with slip stream exposure. To meet construction requirements for a flat surface.
Brazier	Riveting of surfaces with slip stream exposure. Large head advantageous when riveting thin metal.
Flat	Riveting internal structures requiring clearance.
Round	Possesses high strength. Resists tension.
Universal	To replace all protruding head rivets when present stocks are depleted.

RIVET EDGE DISTANCE.—The minimum edge distance for countersunk rivets is 2½D (D equals diameter of rivet). Raised head rivets should have a minimum edge distance od 2D.

Chart 65.—Drill sizes for rivets

Rivet shank diameter	Drill No.	Drill decimal
1/16	52	0.0635
3/32	41	.0960
1/8	30	.1285
5/32	21	.1590
3/16	11	.1910
1/4	#F	.2570

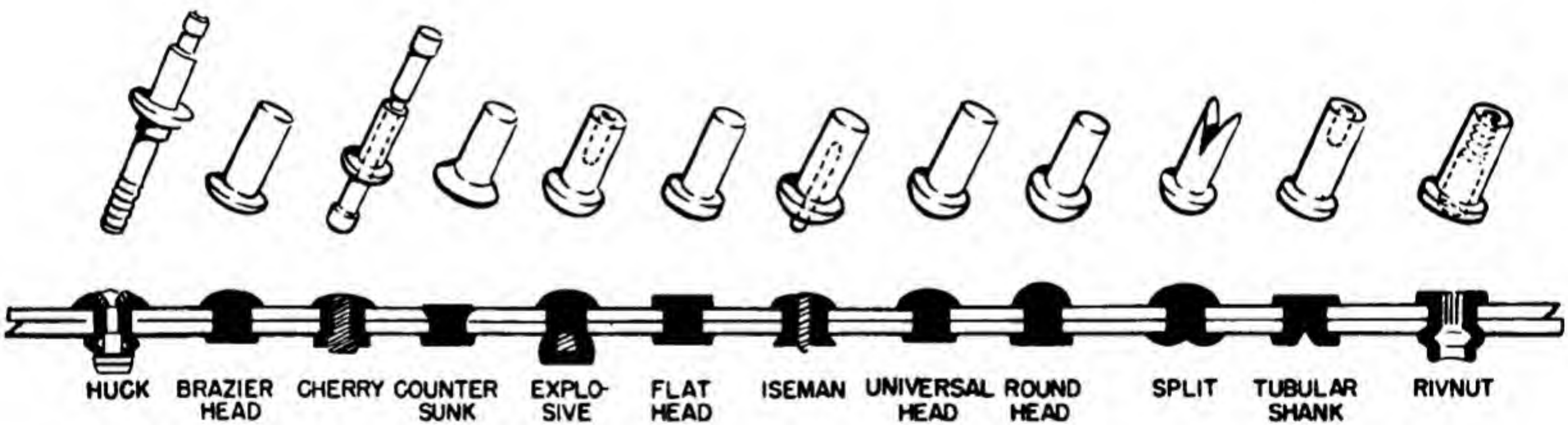


Figure 26.—Types of rivets.

RIVET BUCKED SIZE.—Figure 27 gives a comparison of rivet specifications before and after driving.

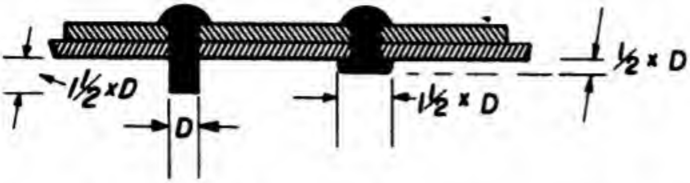


Figure 27.—Rivet dimensions before and after driving.

RIVET PITCH.—The minimum rivet pitch is 3D (D equals diameter of rivet). The thinnest sheet governs the maximum rivet spacing which is 24T (T representing the thickness of the thinnest sheet being riveted).

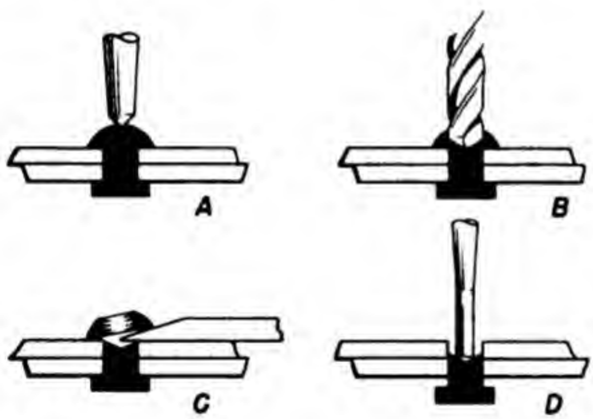


Figure 28.—Removing a rivet.

Chart 66.—Cleco color code

Size (inches)	Color
3/32	Cadium.
1/8	Copper.
5/32	Black.
3/16	Brass.

Diameter in inches		3/32	1/8	5/32	3/16	1/4
Length of rivet in inches	Dash No. for rivet	Max. grip	Max. grip	Max. grip	Max. grip	Max. grip
1/8	-2	0	0	0	0	0
3/16	-3	.039	0	0	0	0
1/4	-4	.102	.063	.024	0	0
5/16	-5	.164	.125	.086	.047	0
3/8	-6	.222	.188	.149	.110	.031
7/16	-7	.274	.250	.211	.172	.094
1/2	-8	.322	.313	.274	.235	.157
9/16	-9	.367	.375	.336	.297	.219
5/8	-10	.412	.433	.399	.360	.281
11/16	-11	.459	.485	.461	.422	.344
3/4	-12	.511	.533	.519	.485	.407
13/16	-13	.573	.575	.571	.547	.469
7/8	-14	.634	.613	.619	.610	.531
15/16	-15	.694	.654	.661	.667	.594
1	-16	.757	.700	.699	.715	.657

BLIND RIVETS—MECHANICALLY EXPANDING TYPES

Cherry rivets (blind type) are designed for difficult riveting jobs in places where access to both sides of the work is impossible. They are applied by one operator using a special gun which exerts a pulling force to form a head on the blind side of the rivet. Another mechanically expanding type blind rivet is the huck rivet, a product of the Huck Manufacturing Co., Detroit, Mich. It is also used where access is available to only one side of the work.

Flush-type blind rivets shall not be used to replace solid type flush rivets in the primary structure. The use of brazier-head blind rivets is permitted only in blind applications or where access is extremely difficult. In blind applications, except for those applications prohibited by Specification 43R7 (Aer) (which supersedes Specification R–23a), brazier-head solid rivets may be replaced by brazier-head blind rivets of the next larger size.

SIZES.—Fasteners of the Cherry rivet type are available in different diameters—1/8, 5/32, and 3/16 inch, ranging in nominal grip length from 0.063 to 0.375. Follow chart 68 as a guide for selection of grip lengths. Replace Cherry rivets with Cherry rivets of the same size. Conventional type rivets require the next larger size Cherry rivet as a replacement.

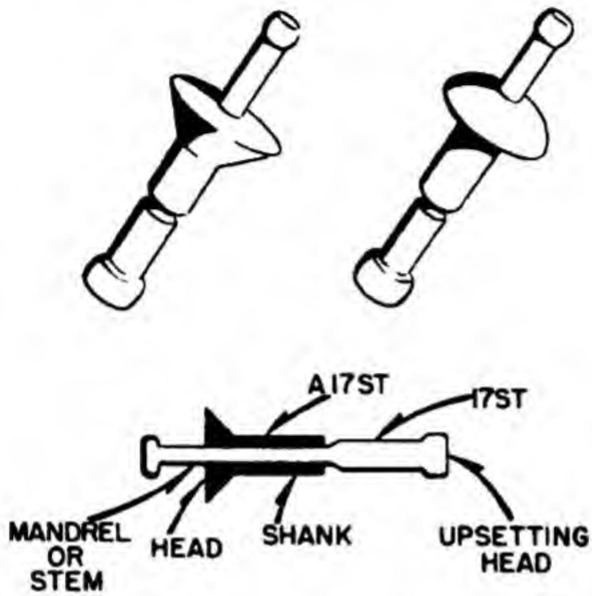


Figure 29.—Cherry rivets.

REPLACEMENTS.—An explosive rivet may be replaced by an explosive rivet of the same size. To replace a conventional rivet with an explosive rivet use the next larger size.

LIMITATIONS.—Explosive rivets are limited in their use. They should never be used to repair:

1. Fuel or oil tanks.
2. Inflammable materials.
3. Dimpled sheets.
4. Surfaces impossible to hold in contact while exploding rivet.
5. Hulls or floats, unless properly sealed.
6. Heavily stressed parts.

Before using refer to *Structural Repair Manual* of airplane concerned.

HI-SHEAR RIVETS

Hi-Shear rivets are a special type high strength rivet used in heavy ribs (bulkheads) and wing spars. The pin is made from an alloy steel and cadmium plated. The collar part is A17ST aluminum alloy.

Coding and interpretation

NAS 178 —8 —6

- —6 — Minimum grip length in 16ths.
- —8 — Nominal diameter in 32ds.
- NAS 178 — NAS Standard drawing number.

Removal of hi-shear rivets.—With a chisel made from a small pin punch, remove collar by cutting in two places (opposite sides), then the stud may be driven from the hole.

Hi-Shear rivets shall be replaced with Hi-Shear rivets, AN steel clevis bolts, or AN Hex head bolts of the same or next larger size, provided an edge distance of 1.5 times the diameter is maintained. Where a countersunk screw would be required to replace a Hi-Shear rivet, a special structural screw, such as an AN or NAF standard, may be used. Hi-Shear rivets, clevis bolts, Hex head bolts, or special screws used for replacement shall have been heat treated to 125,000 p. s. i. ultimate tensile strength or better.

A17ST aluminum alloy rivets are purchased in the heat-treated condition and shall be used in this condition. In strength, they are inferior to 17ST rivets. Comparative physical properties of aluminum alloy rivets are shown on page 127.

Limitations in use of cherry rivets.—Rivets of this type are not to be used in structures subject to heavy stresses. Repairs to hulls, floats or tanks should not be attempted with Cherry rivet fasteners.

	A17ST rivets	17ST rivets	17ST-DH rivets	24ST rivets	56S rivets
Design shearing strength	30,000 p. s. i.	34,000 p. s. i.	38,000 p. s. i.	41,000 p. s. i.	27,000 p. s. i.
Head marking	(Dimple)	(Raised teat)	(Raised teat)	(Double raised dash).	(Raised cross).

Chart 68.—Material thickness table

Rivet code No.	Nominal	Minimum	Maximum
2	0. 063	0. 030	0. 077
4	. 1125	. 078	. 140
6	. 1875	. 141	. 203
8	. 25	. 204	. 265
10	. 3125	. 266	. 328
12	. 375	. 329	. 391

Chart 69.—Drill sizes

Series	Diameter	Hole size	Drill size
CR-162 and CR-163	1/8	0. 128 to 0. 132	30
	5/32	. 160 to . 164	20
	3/16	. 192 to . 196	10
CR-178 and CR-179	1/8	. 137 to . 141	29
	5/32	. 177 to . 181	16
	3/16	. 206 to . 210	5

EXPLOSIVE RIVETS

CODE NUMBER AND INTERPRETATION—

DR—	127—	A—	6
Dupont rivet	Shank diameter (0.127)	Brazier head	Nominal grip (0.06)

DR—	134—	100—	10
Dupont rivet	Shank diameter (0.134)	100° c'sunk	Nominal grip (0.10)

Chart 70.—Selection of brazier head explosive rivets

Grip length or total thickness to be riveted	Proper size brazier head rivet to use		
	If 1/8 inch diameter is indicated	If 5/32 inch diameter is indicated	If 3/16 inch diameter is indicated
0.040 inches	DR-134A-4		
0.060 inches	DR-134A-6	DR-173A-6	
0.080 inches	DR-134A-8	DR-173A-8	DR-204A-8.
0.100 inches	DR-134A-10	DR-173A-10	DR-204A-10.
0.120 inches	DR-134A-12	DR-173A-12	DR-204A-12.
0.140 inches	DR-134A-14	DR-173A-14	DR-204A-14.
0.160 inches	DR-134A-16	DR-173A-16	DR-204A-16.
0.180 inches	DR-134A-18	DR-173A-18	DR-204A-18.
0.200 inches	DR-134A-20	DR-173A-20	DR-204A-20.
0.220 inches		DR-173A-22	DR-204A-22.
0.240 inches		DR-173A-24	DR-204A-24.

Chart 71.—Selection of countersunk explosive rivets

Grip length or total thickness to be riveted	Proper size countersunk rivet to use		
	If 1/8 inch diameter is indicated	If 5/32 inch diameter is indicated	If 3/16 inch diameter is indicated
0.060 inches	DR-134-100-6		
0.080 inches	DR-134-100-8	DR-173-100-8	
0.100 inches	DR-134-100-10	DR-173-100-10	DR-204-100-10.
0.120 inches	DR-134-100-12	DR-173-100-12	DR-204-100-12.
0.140 inches	DR-134-100-14	DR-173-100-14	DR-204-100-14.
0.160 inches	DR-134-100-16	DR-173-100-16	DR-204-100-16.
0.180 inches	DR-134-100-18	DR-173-100-18	DR-204-100-18.
0.200 inches	DR-134-100-20	DR-173-100-20	DR-204-100-20.
0.220 inches		DR-173-100-22	DR-204-100-22.
0.240 inches		DR-173-100-24	DR-204-100-24.

Chart 72.—Pilot and finish drill sizes

Rivet diameter	Rivet number	Pilot drill	Finish drill
1/8 inch brazier	DR-134A	No. 31 or smaller	3.25 mm. (0.1275").
1/8 inch (100°) countersunk.	DR-134-100	No. 30 or smaller	No. 29 (0.136").
5/32 inch brazier	DR-173A	No. 22 or smaller	No. 17 (0.173").
5/32 inch (100°) countersunk.	DR-173-100	No. 22 or smaller	No. 17 (0.173").
3/16 inch brazier	DR-204A	No. 12 or smaller	No. 6 (0.204").
3/16 inch (100°) countersunk.	DR-204-100	No. 12 or smaller	No. 16 (0.204").

RIVNUTS

Rivnuts (53SW) are internally threaded and so designed that installation does not require a bucking bar. They are available with a 0.035" thick flat head and a 100° or a 115° countersunk head. They come in sizes 6-32, 8-32 and 10-32 with open or closed ends, and are used for de-icer boot attachment, accessories, and as nut plates, etc.

Chart 73.—Rivnut grip length—flat head

[6-32, 8-32, and 10-32 Rivnuts]

Thickness range (inch)	Thickness range (inch)	Thickness range (inch)
0. 045	0. 140	0. 200
. 075	. 160	. 220
. 100	. 180	. 240
. 120		

Chart 74.—Rivnut grip length—countersunk

100° COUNTERSUNK HEAD—ALUMINUM ALLOY
0.048 INCH HEAD THICKNESS

Size and threads	Grip (inch)	Goodrich part No.
6–32	0.091	A6B91
	.146	A6B146
6–32	.091	A6–91
	.106	A6–107
	.121	A6–121
	.166	A6–166
	.206	A6–206
8–32	.091	A8–91
1–32	.091	A10–91

0.063 INCH HEAD THICKNESS

Size and threads	Grip (inch)	Goodrich part No.
6–32	0.201	A6KB201
8–32	.106	A8K106
10–32	.106	A10KB106
6–32	.161	A6–161
6–32	.106	A6K106
	.136	A6K136
	.161	A6K161
	.181	A6K181
	.201	A6K201
	.221	A6K221
8–32	.106	A8K106
10–32	.106	A10K106
	.136	A10K136

115° COUNTERSUNK HEAD—ALUMINUM ALLOY
.063 INCH HEAD THICKNESS

Size and threads	Grip (inch)	Goodrich part No.
6–32	0.107	A6B107
10–32	.137	A10KB137
10–32	.162	A10–162
6–32	.136	A6K137
10–24	.107	A1024K107
	.137	A1024K137
	.162	A1024K162

DRILL SIZES.—Consult chart 75 for lead hole and finished hole size for flathead rivnuts.

Chart 75.—Drill sizes for flathead rivnuts

Size rivnut	Head thickness	Lead drill	Body drill
No. 6–32	0.035	No. 19	No. 12.
No. 8–32	.035	No. 8	No. 2.
No. 10–24	.035	No. 1	¼″.
No. 10–32	.035	No. 1	¼″.

MACHINE SCREWS

CODE NUMBERS AND INTERPRETATION

AN–500 A C 4 –3

–3: Lengths in 16ths.

4: Dia. and threads per inch.

C: Corrosion resisting steel.
B—Brass.
No letter—cadmium plated steel.

A: Drilled head.
No letter—without drilled head.

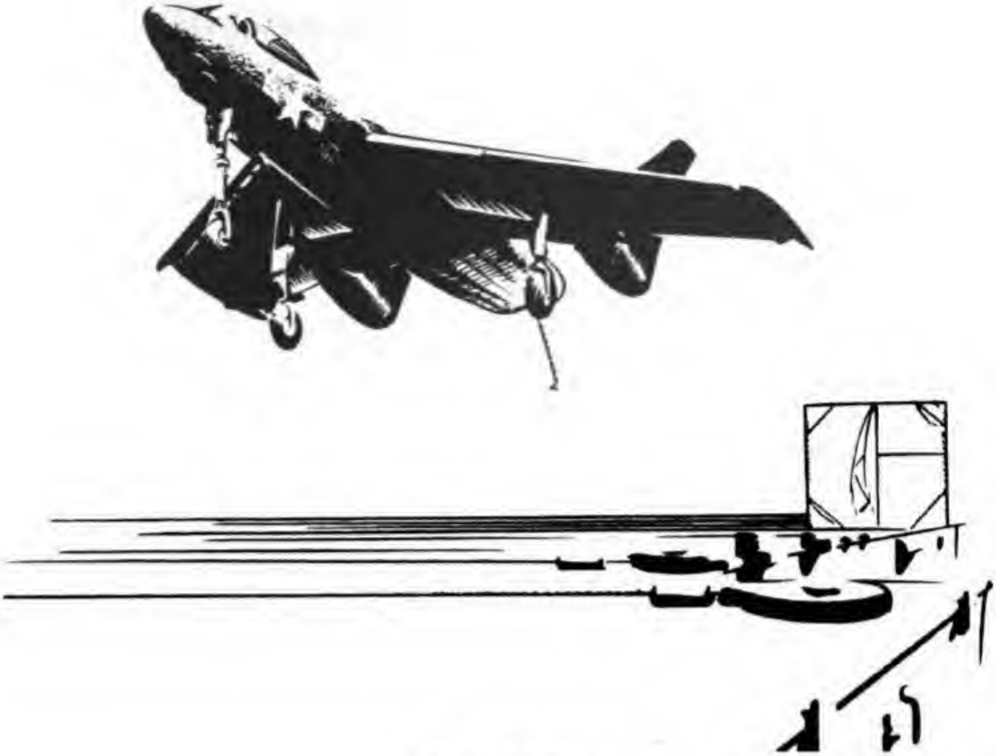
AN–500: AN Standard drawing No.

AN-505 B 6 R 14

- Length in 16ths. (14)
- Recessed head. (R)
  No letter—slotted head.
- Dia. and threads per inch (6–32). (6)
- B—Brass. (B)
  C—Corrosion resisting steel.
  DD—Aluminum alloy.
  No letter—Steel cadmium plated.
- AN Standard drawing No. (AN-505)

Chart 76.—Bolt and screw sizes

Coarse		Fine	
Size and number of threads	Diameter	Size and number of threads	Diameter
		0–80	0. 060
1–64	0. 073	1–72	. 073
2–56	. 086	2–64	. 086
3–48	. 099	3–56	. 099
4–36	. 112		
4–40	. 112	4–48	. 112
5–40	. 125	5–44	. 125
6–32	. 138	6–40	. 138
8–32	. 164	8–36	. 164
10–32	. 190	10–32	. 190
12–24	. 216	12–28	. 216
¼–20	. 250	¼–28	. 250



CHAPTER 8

STRUCTURAL REPAIR

BEND ALLOWANCE AND BEND ALLOWANCE TERMS

Figure 30 illustrates a typical 90° bend problem encountered in fabrication of sheet metal parts, followed by solution, layout, and location of bend lines necessary for fabrication.

DETERMINE BEND ALLOWANCE FOR 90° BEND

LENGTH OF EACH SECTION—
Section A and section E
$A = \frac{3}{4} - (R + T)$
R = inside radius of bend
T = metal thickness
$A = \frac{3}{4} - (\frac{1}{8} + 0.040) = 0.750 - (0.125 + 0.040)$ or $0.750 - 0.165$, which gives $0.585 (\frac{37}{64})$; also the length of section E, since it has an identical length and radius.
Section C
$C = 3'' - (2R + 2T)$

2R and 2T = two inside radii and two metal thicknesses

$C = 3'' - (0.250 + 0.080)$, or $3 - 0.330$

$C = 2.67$, or $2 - \frac{43}{64}$.

Section B and Section D—Bend Allowance.

Bend allowance (metal consumed in a bend) for 1° of bend when using a ⅛-inch radius and 0.040 material is 0.00249.

$B = 90 \times 0.00249 = 0.224$, or $\frac{7}{32}$

$D = 90 \times 0.00249 = 0.224$, or $\frac{7}{32}$

OVER-ALL LENGTH.—Add the length of the unbent and bent sections (A+B+C+D+E) to determine the total amount of metal required, which is 4.288 $(4 + \frac{9}{32})$ in the above problem.

BEND LINE LOCATION.—First determine the sequence of bends. In the above example X indicates the edge (end) of the material to go into the brake. Make bend No. 2 first. For bend-line location with reference to brake jaw refer to figure 45.

No. 1 bend line $= \frac{37}{64} + \frac{1}{8} = \frac{45}{64}$

No. 2 bend line $= \frac{37}{64} + \frac{7}{32} + 2\frac{43}{64} + \frac{1}{8} = 3\frac{1}{64}$

(NOTE: ⅛ is added because it is the radius of the bend to be made.)

FORMING ALUMINUM (HAND)

Repairs often require that parts be formed by hand from sheet stock, which is done by using different shaped mallets and hardwood form blocks. The metal is held between form blocks and formed with a mallet and wedge.

SPRING BACK.—The form block (block around which the metal is formed) shown in figure 31 requires a bevel of 3 to 11° depending upon the metal's hardness, to compensate for spring back.

SHRINKING ALUMINUM.—Areas that are to be shrunk are first crimped. The crimps are put into the metal flange with round-nose pliers or by hammering it over a V-block. Crimp as necessary to produce the desired curvature and then clamp the part in a shrinking block as shown in figure 32 and flatten out the crimps.

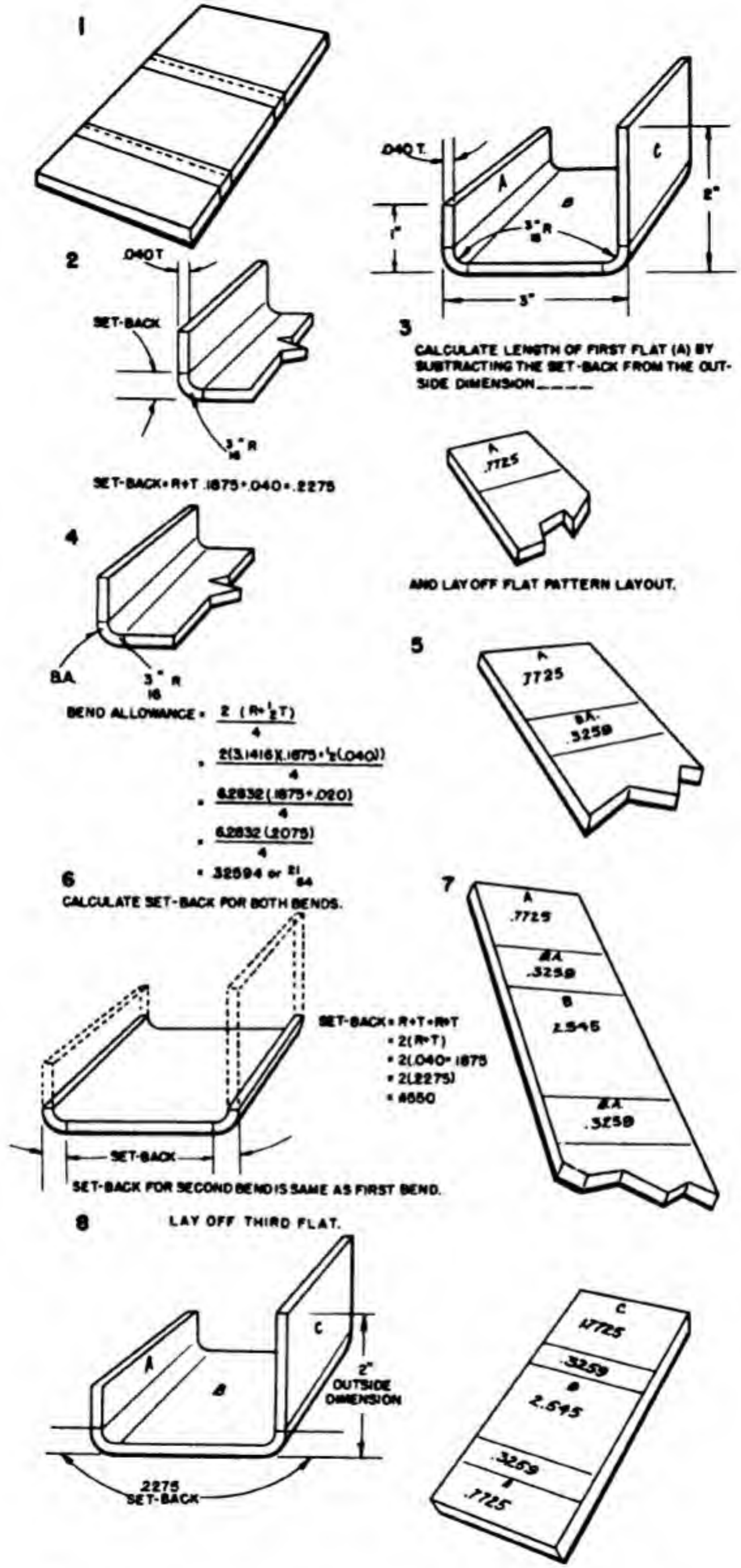


Figure 30.—Typical 90° bend allowance problem.

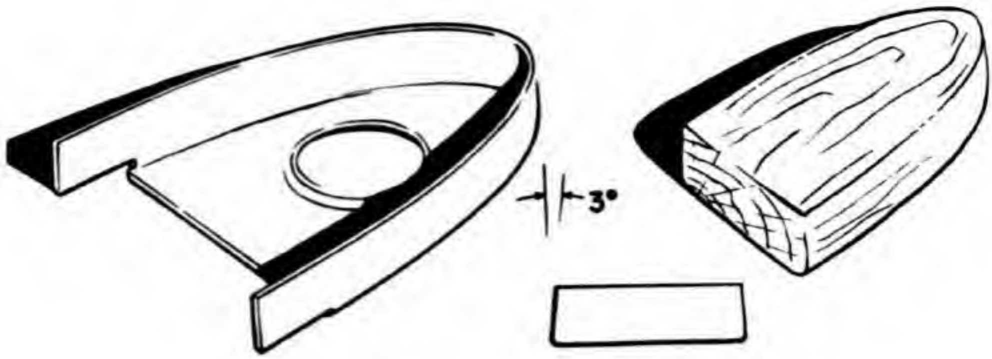


Figure 31.—Formed nose rib and block.

JOGGLE.—A joggle produces a level surface even though two pieces of metal overlap each other as shown in figure 33.

Joggles may be made in a cornice brake unless joggling extruded shapes. When joggling extruded shapes, place the metal between the joggle blocks and force the joggle by clamping a vise and then flatten the bulge, which may appear on the opposite angle, with a mallet.

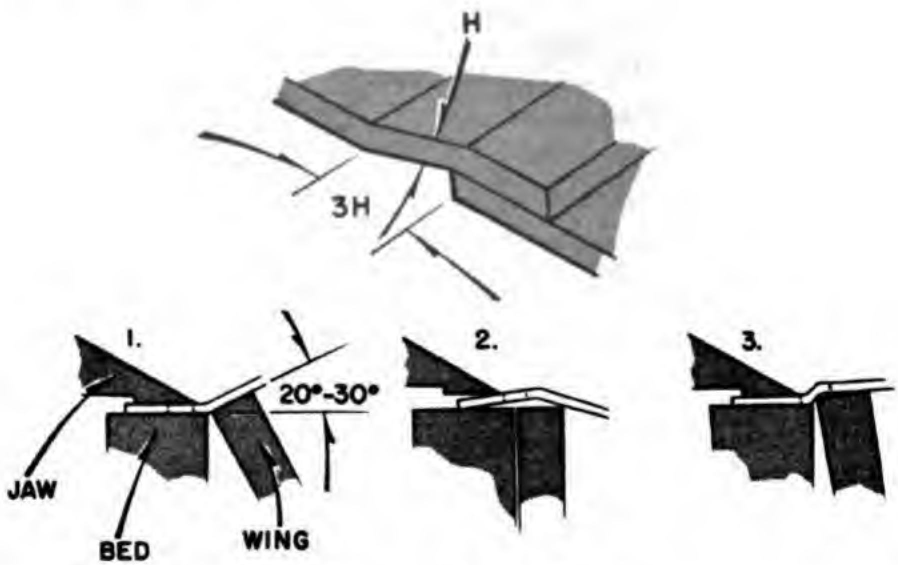


Figure 32.—Joggle specifications.

METALITE

Metalite consists of balsa wood sandwiched between sheets of aluminum alloy. For full particulars concerning repairs that may be made and the manner in which they are to be

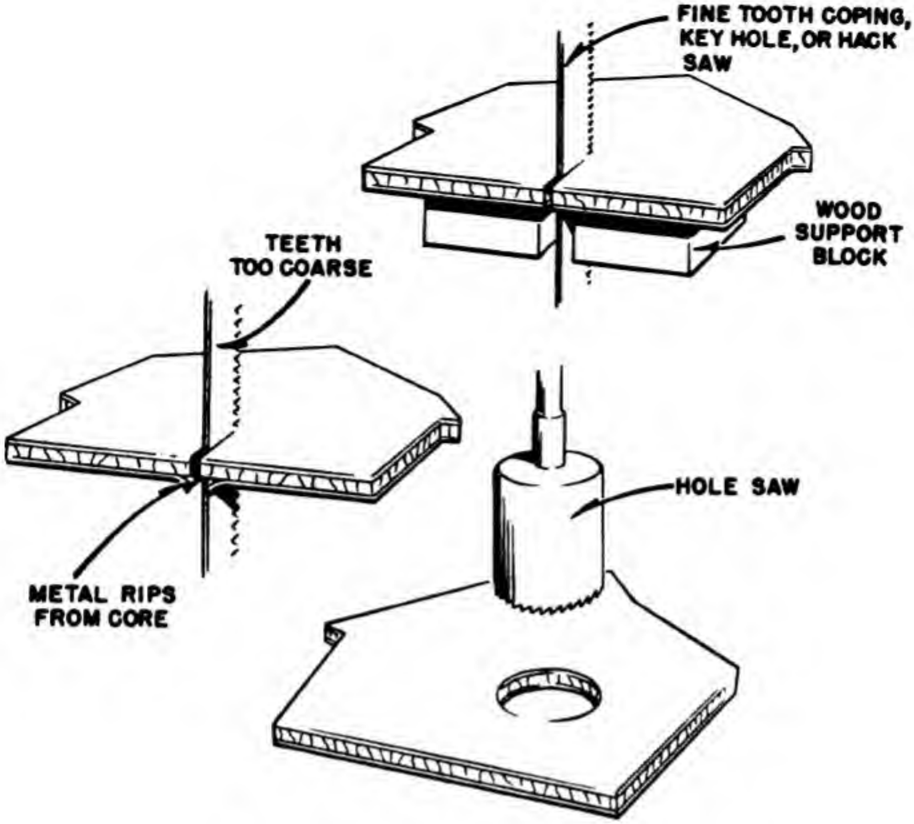


Figure 33.—Cutting metalite.

effected, refer to the *Structural Repair Manual* for plane in question.

Cutting metalite.—The metal is easily torn from the balsa core, which requires that special care must be exercised when cutting as shown in figure 33.

Riveting.—Due to the crushing effect on the balsa core, standard rivets are not used. Instead, Huck blind, semi-tubular, or Cherry rivets are used. In emergency, dural steel bolts may be used. Countersinking by pressing or dimpling is necessary since attachments must be flush.

RIVET SIZE AND EDGE DISTANCE

Shank size.—Rivets under 3/32-inch in diameter should not be used. The maximum rivet diameter may be expressed as 2½ T–3T, (T representing the thickness of heaviest sheet). The minimum diameter is equivalent to the thickness of the thickest sheet.

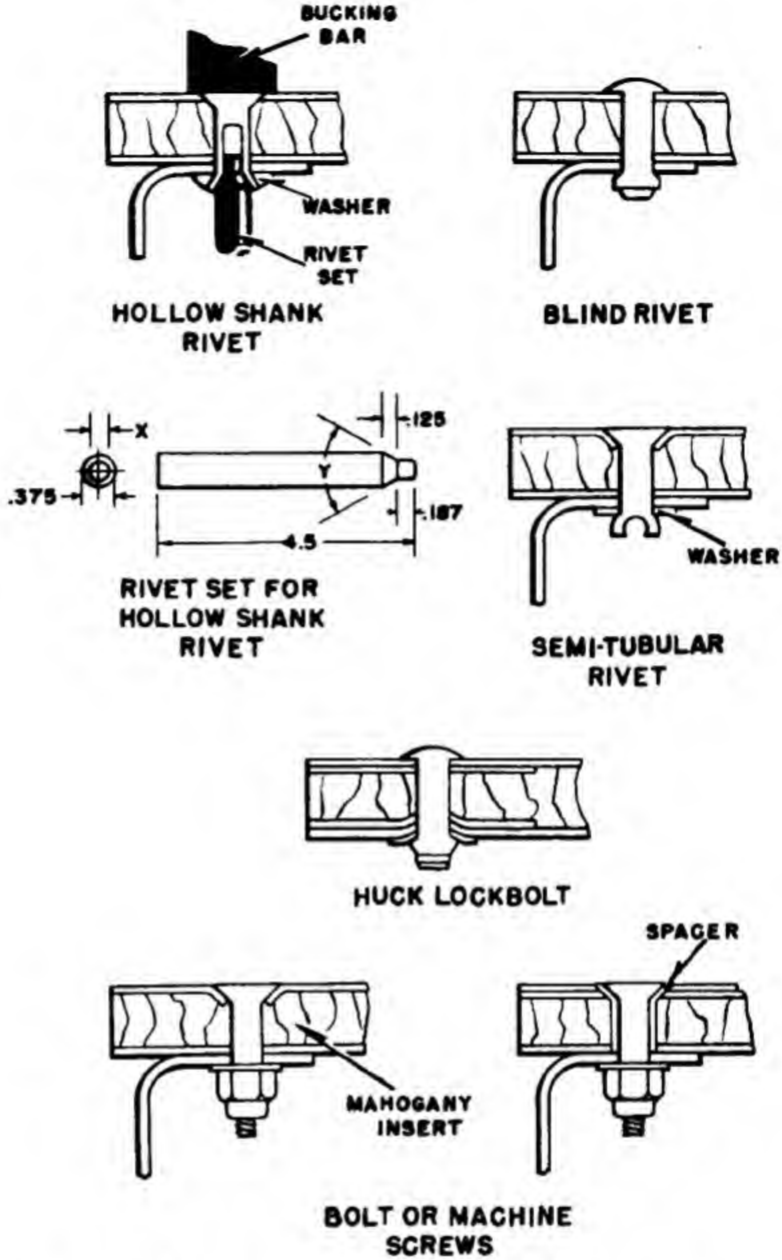


Figure 34.—Installing bolts and rivets in metalite.

RIVET EDGE DISTANCE.—The minimum edge distance for countersunk rivets is 2½ D (D—diameter of rivet shank). Minimum edge distance for raised head type is 2D (D—diameter of rivet shank).

RIVET SPACING.—If two rows of rivets are used, the rivets should be laid out and staggered as shown in figure 37.

SMALL HOLE REPAIR.—Small holes may be repaired as illustratcd in figure 36. Such a repair is applicable to either nonstressed or stressed skin.

BULKHEAD REPAIRS.—Partitions such as belt frames, reinforcing rings and former rings are considered as bulkheads. Special care must be exercised while fabricating repairs of this type in that bulkheads are subject to loads. Various repairs are shown in the following illustrations.

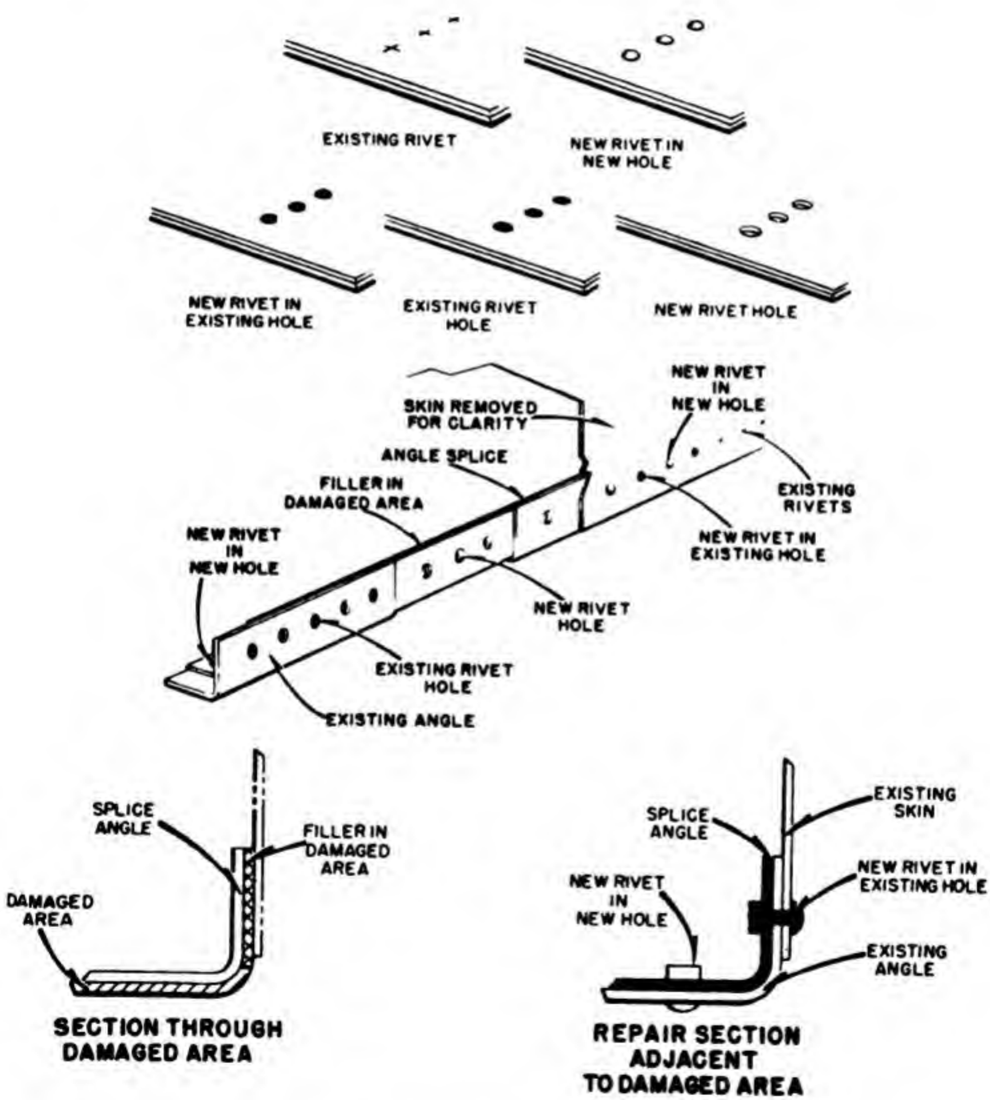


Figure 35.—Aircraft skin repair code.

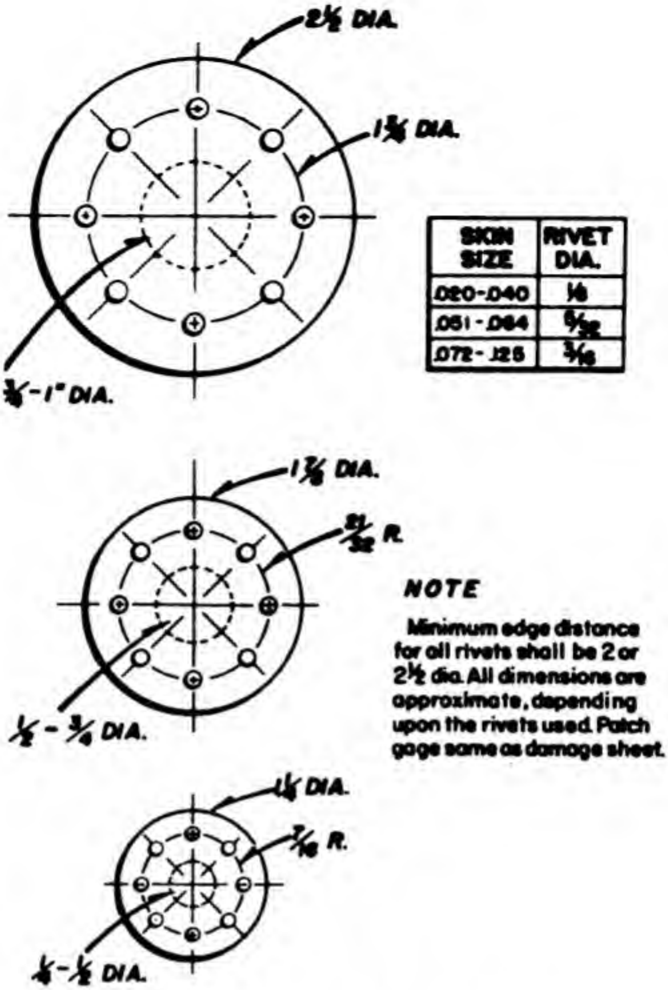


Figure 36.—Lap patch for small holes.

Rib repair.—Ribs are classified into two groups, depending upon their construction, as illustrated in figure 40.

Typical rib repairs are shown in the following illustrations. The capstrip repair shown in figure 42 illustrates a typical

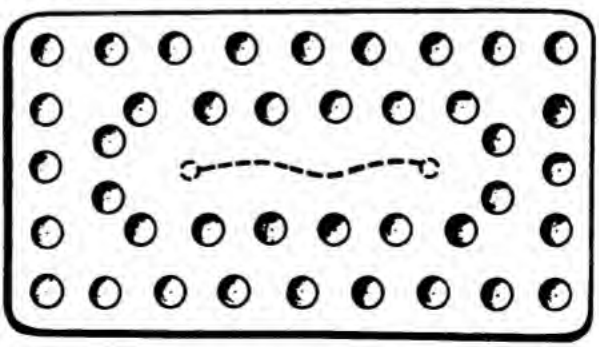


Figure 37.—Repairing cracks in stressed skin.

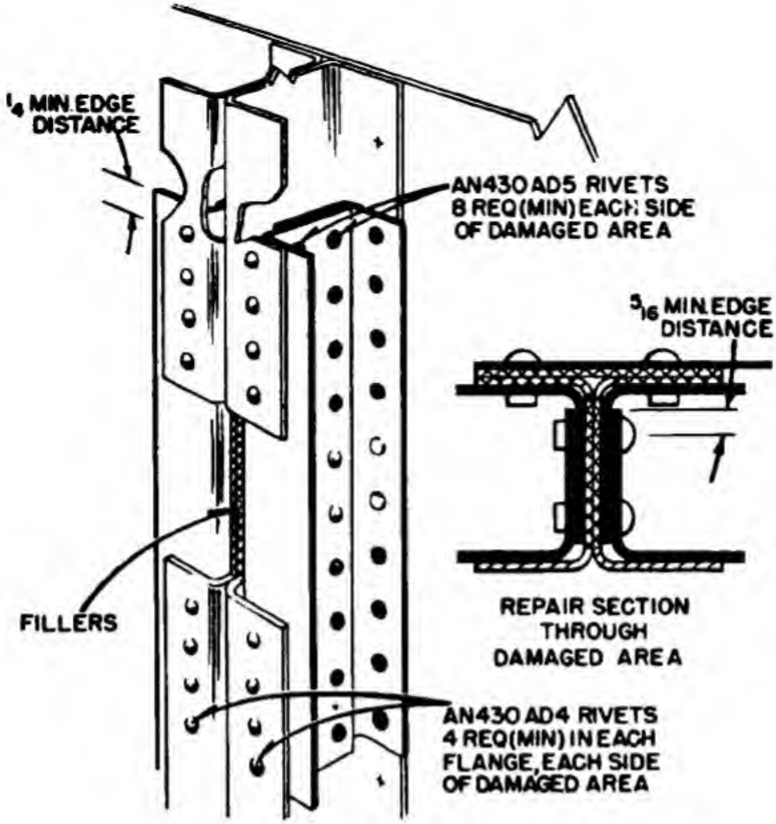


Figure 38.—Repair of belt frame by splicing.

repair of a rib of the trussed type. Ribs that have a buckled web or require a splice are repaired as shown in (A) and (B) of figure 42. Figure 44 illustrates the repair of a cracked lightening hole with a reinforcement.

STRINGER REPAIR.—(Determining number of rivets required.) In figure 46, the total length of damage is 4½

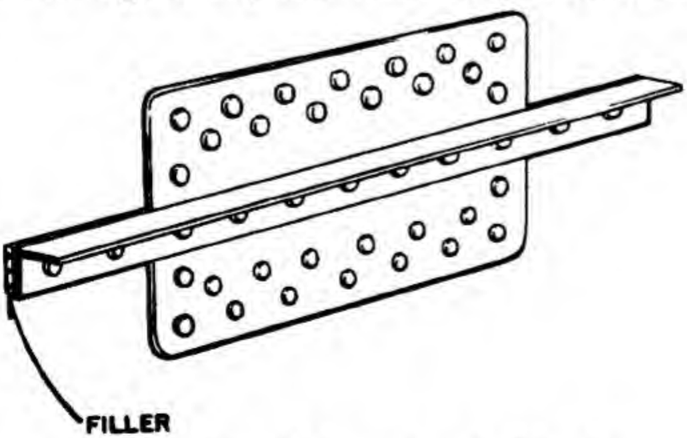


Figure 39.—Web repair on bulkhead.

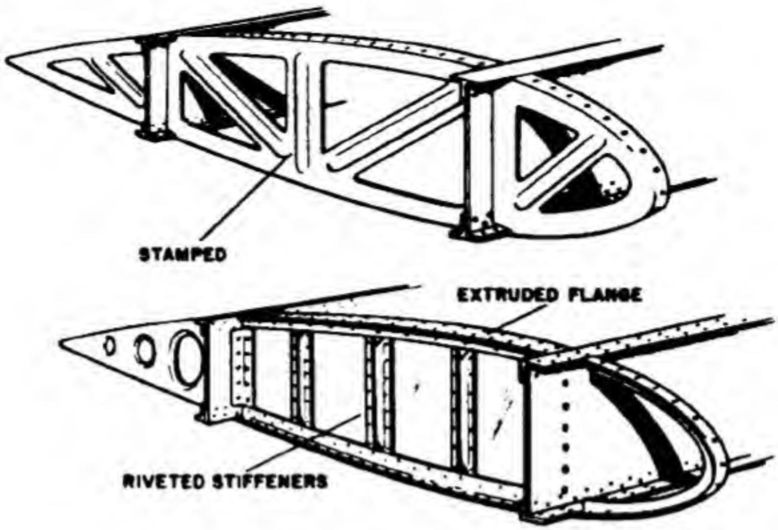


Figure 40.—Wing ribs.

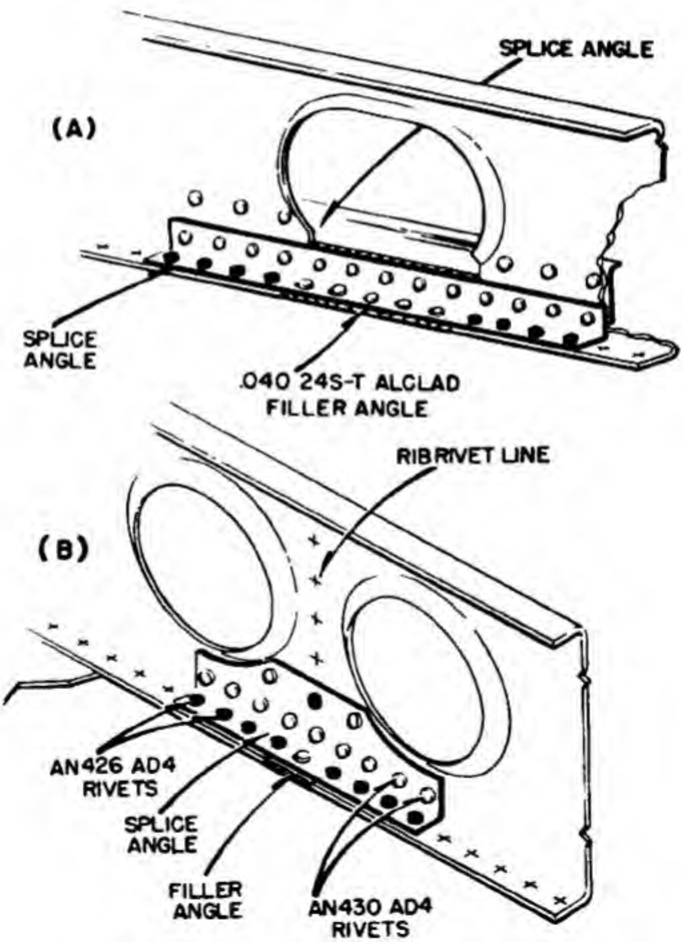


Figure 41.—Repairing rib webs.

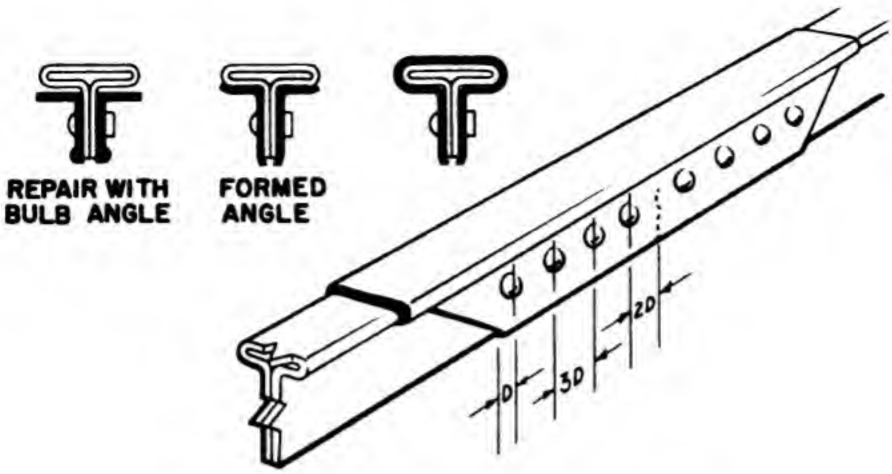


Figure 42.—Repairing damaged capstrip.

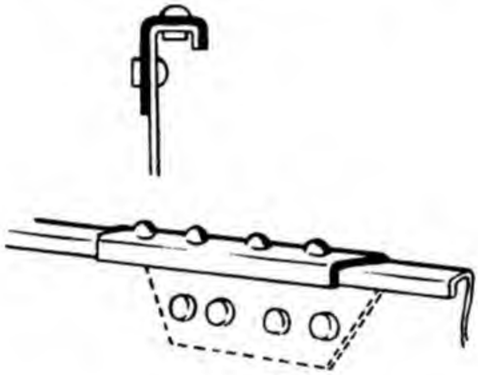


Figure 43.—Repair of flange not riveted to skin.

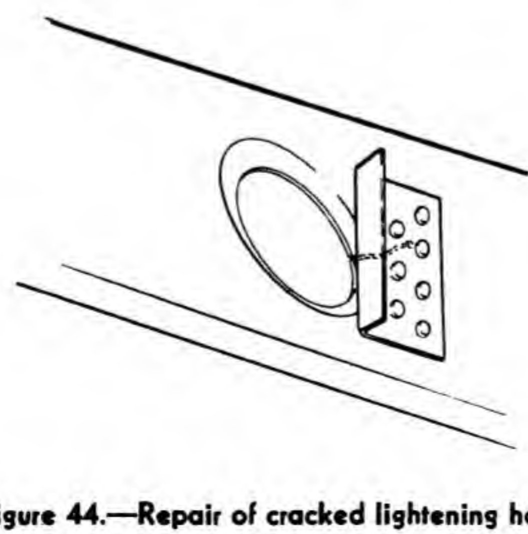


Figure 44.—Repair of cracked lightening hole.

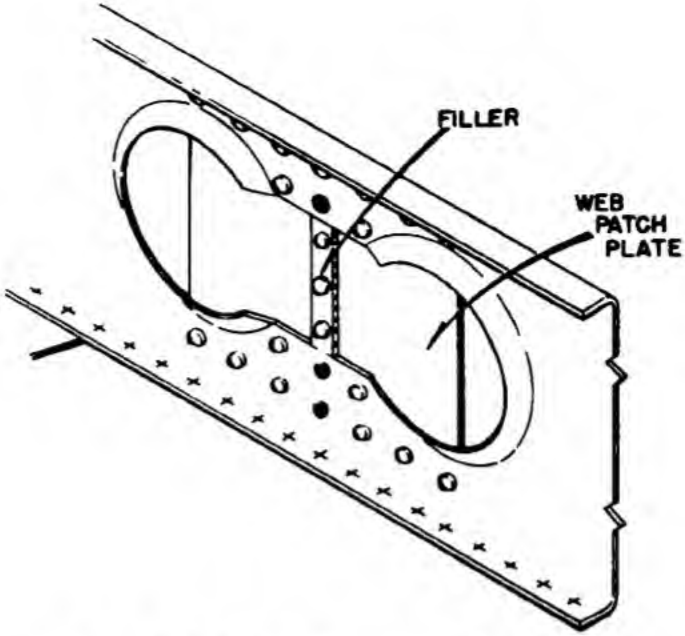


Figure 45.—Typical repair of wing flap rib.

inches. If ⅛ inch, 17ST rivets are used in the repair, chart 77 indicates 3.9 rivets per inch of damage necessary. Rivets per inch (3.9) times length of damage (4½ inches) or 18 rivets are required for one side. Total number of rivets required is 36.

Extruded stock should be used for repairs if available. However, replacements fabricated from sheet stock may be

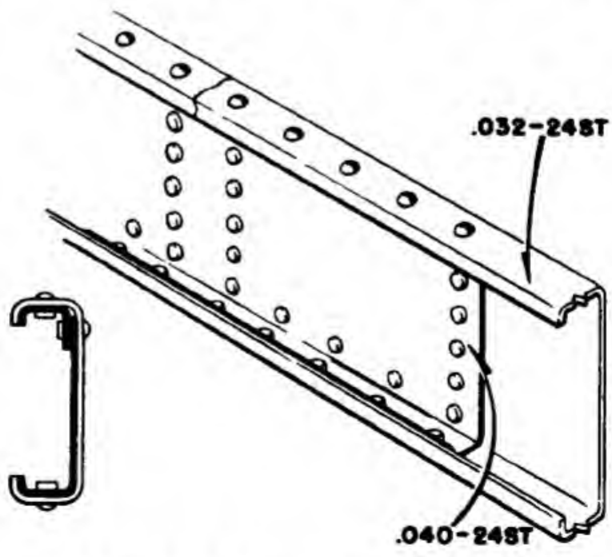


Figure 46.—Typical channel repair.

used providing it is one gage heavier than the original and of the same cross section.

Chart 77.—Rivets required for stringers

Thinnest sheet 24ST gage material	Rivets 1/8 inch		Rivets 5/32 inch		Rivets 3/16 inch	
	A17ST	17ST	A17ST	17ST	A17ST	17ST
0.020	3.9	3.9				
0.025	3.9	3.9				
0.032	4.5	3.9	3.1	3.1		
0.040	5.7	4.7	3.6	3.1	2.6	2.6
0.051	7.3	6.1	4.6	3.9	3.2	2.7
0.064	9.0	7.6	4.8	4.0	3.3	2.8

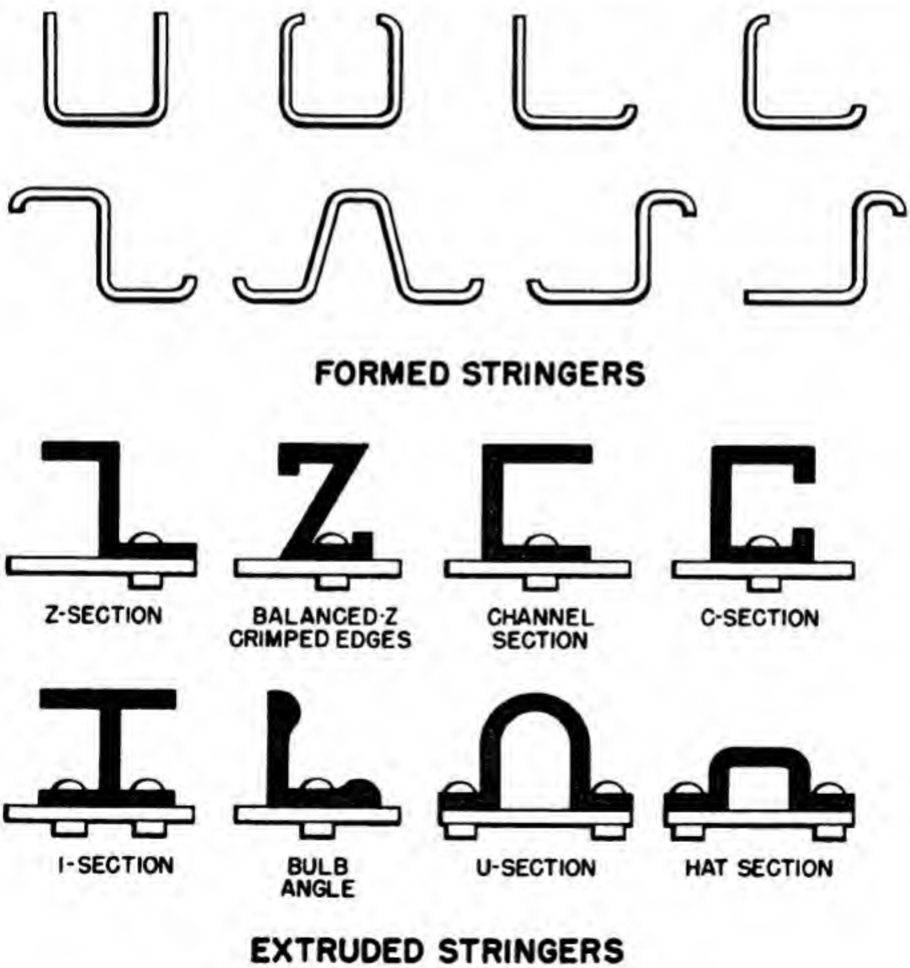


Figure 47.—Extruded and formed stringers.

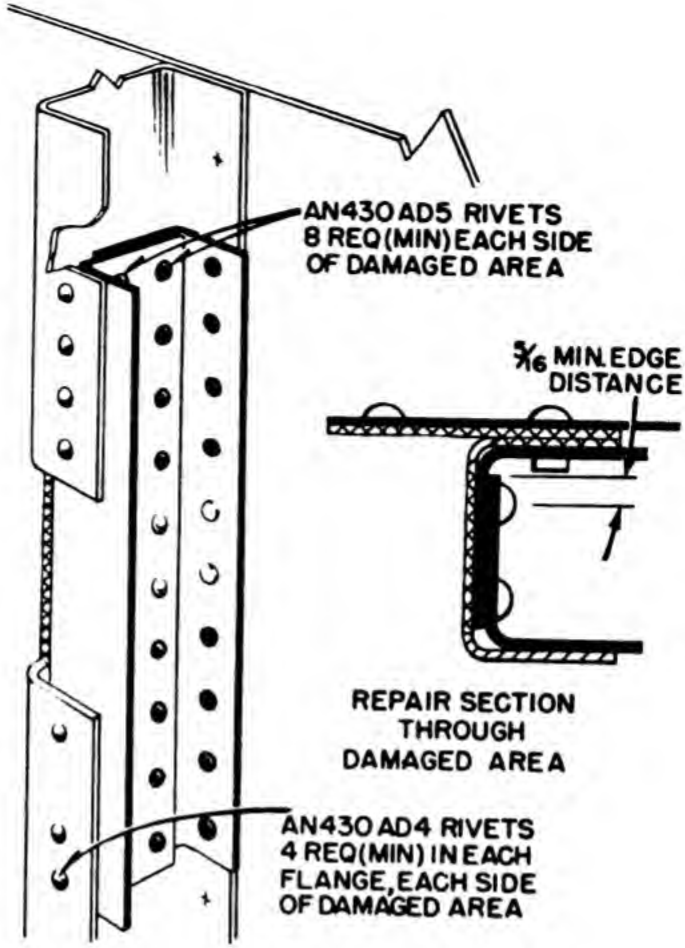


Figure 48.—Splicing damaged channel web.

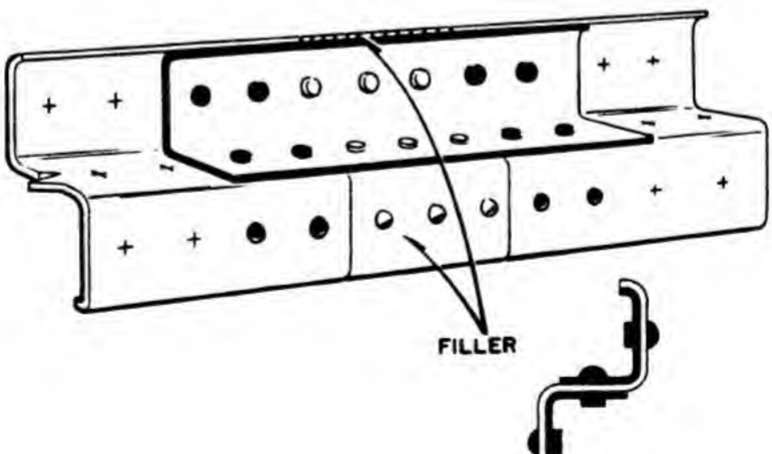


Figure 49.—Splicing damaged Z stringers.

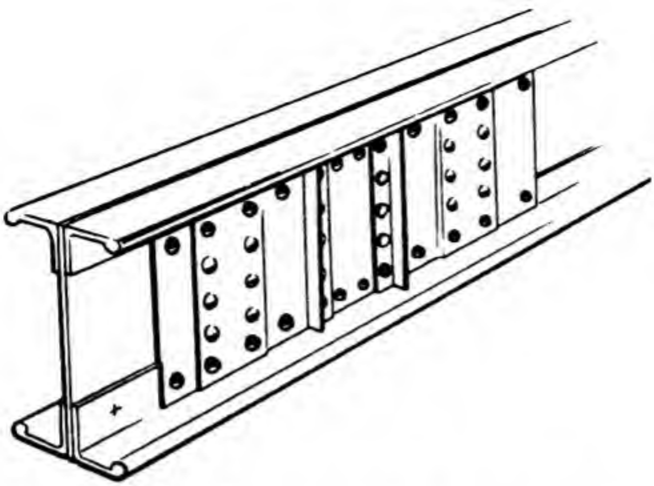


Figure 50.—Repairing holes in spar web.

Spar repairs.—Most repair work consists of splices and installation of reinforcing plates. When making such repairs use metal of an identical alloy and gage. However, one gage heavier metal may be used.

Replacement.—A replacement is necessary if the damaged skin cannot be repaired successfully by patching.

Chart 78.—Sealants for floats and hulls

Type	Characteristic	Use
I	High viscosity sealer	For corner packing or as a faying surface sealer for hull, inspection plates, pontoon, etc.
II	Tape form impregnated fabric.	For higher pressure, used as a seam sealant and insulator for seams involving dissimilar metals.
III	In form of rolled or extruded tape.	Same as type 2, if high pressures do not exist. Has desirable application characteristics.
IV	Material for slushing purposes.	Slushing compound; inaccessible seam leaks may be sealed after repairs have been effected.

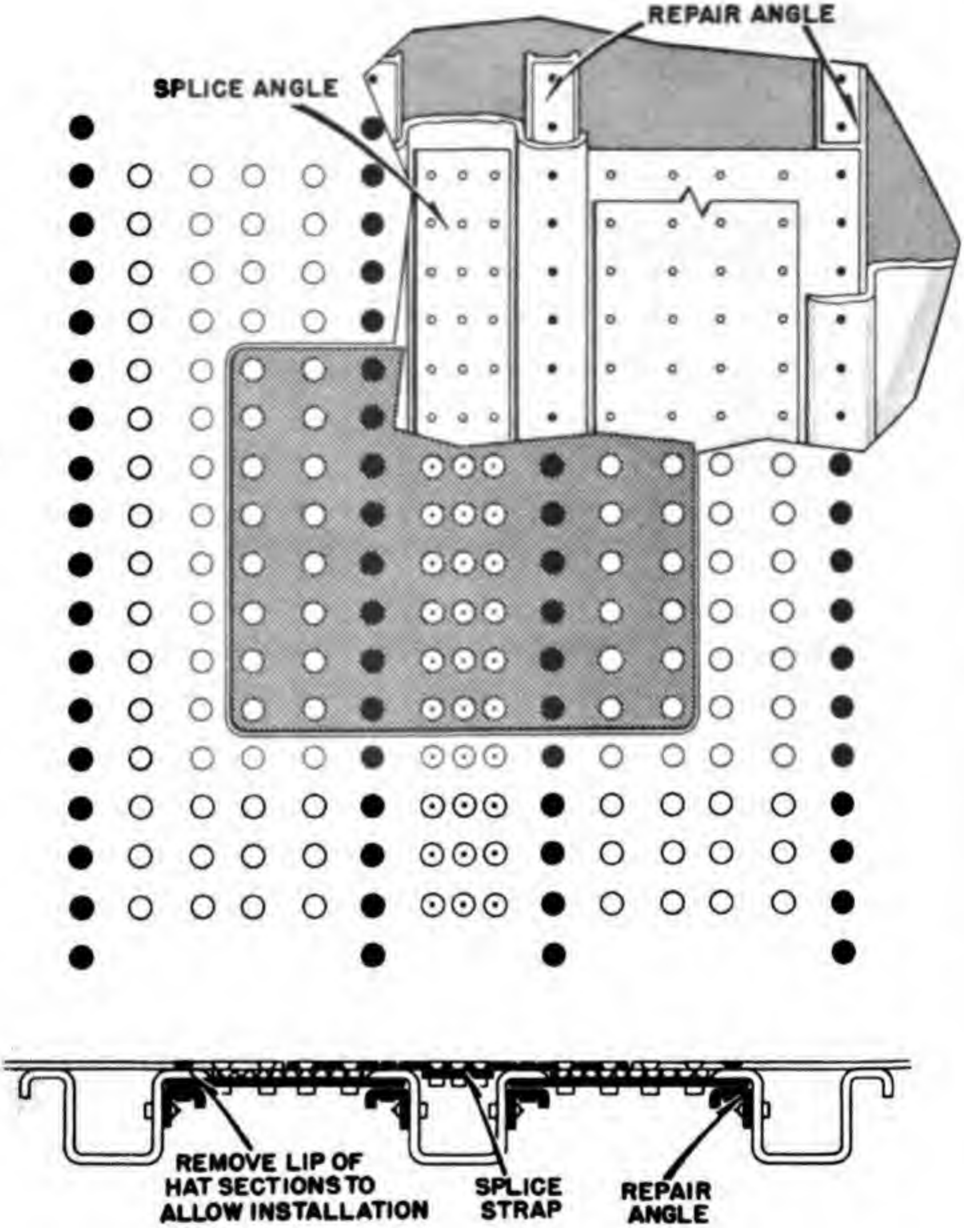


Figure 51.—Replacement when entire panel is not removed.

After determining the extent of the damage, carefully remove the damaged skin in the event the old skin is needed as a template. The replacement panel must restore the original durability and strength without an excessive increase in weight.

WATERTIGHT PATCH.—A watertight lap patch should have the edge of the patch beveled about half of the metal's thickness and then a 15° crimp put in the edge as shown in figure 52.

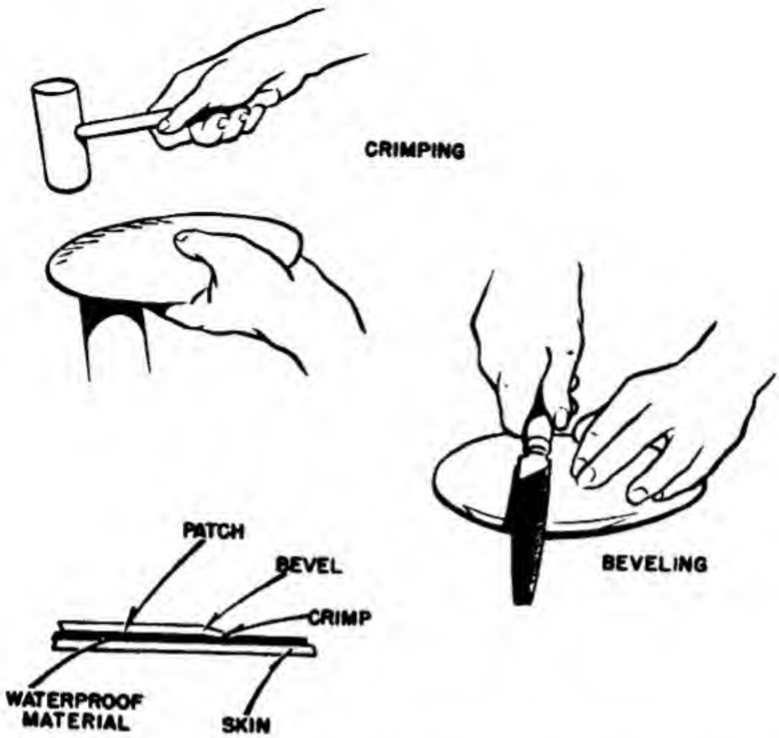


Figure 52.—Crimping and beveling a watertight patch.

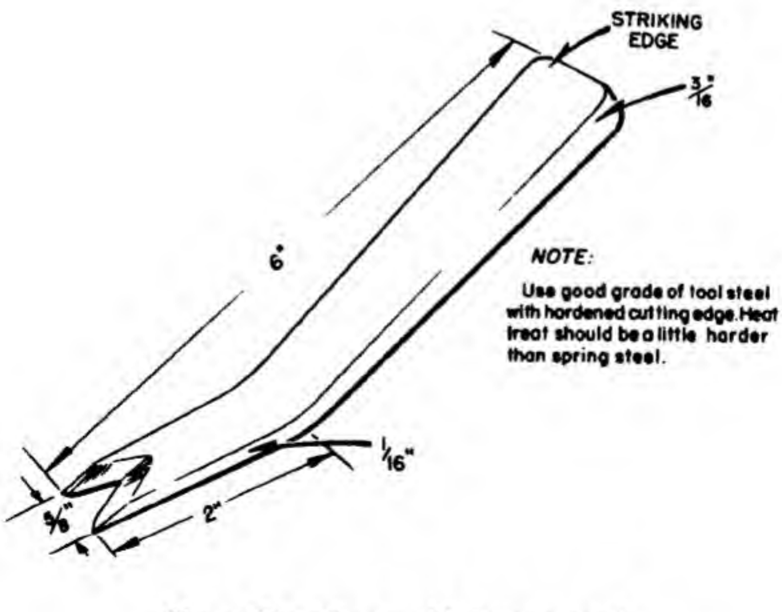


Figure 53.—Spot weld shearing tool.

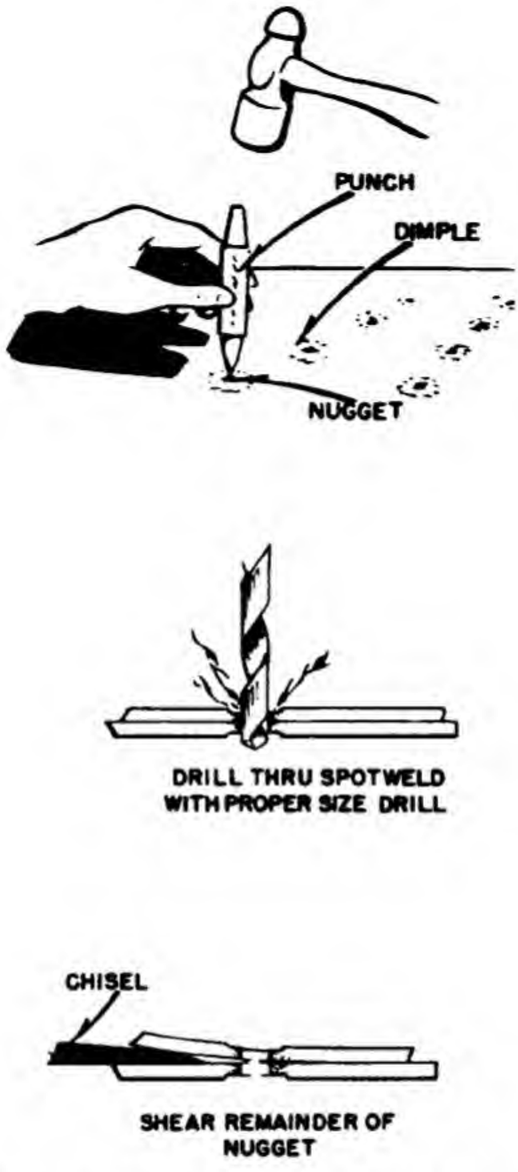


Figure 54.—Shearing spot welds for riveting.

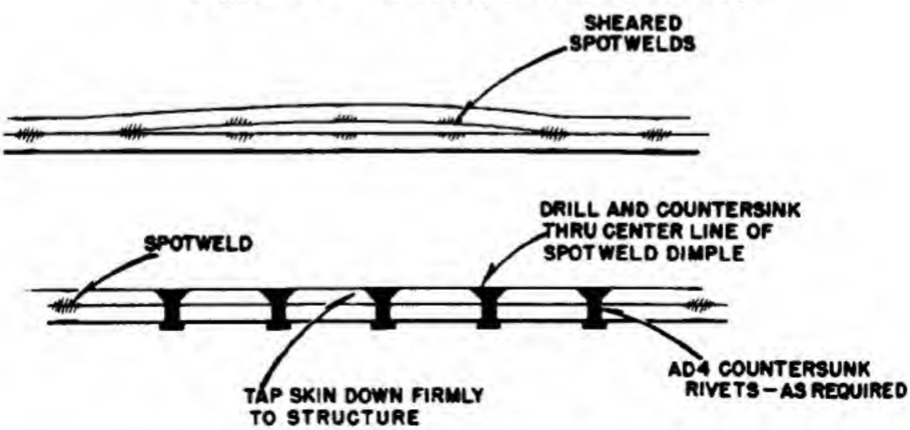


Figure 55.—Repair of sheared spot welds.

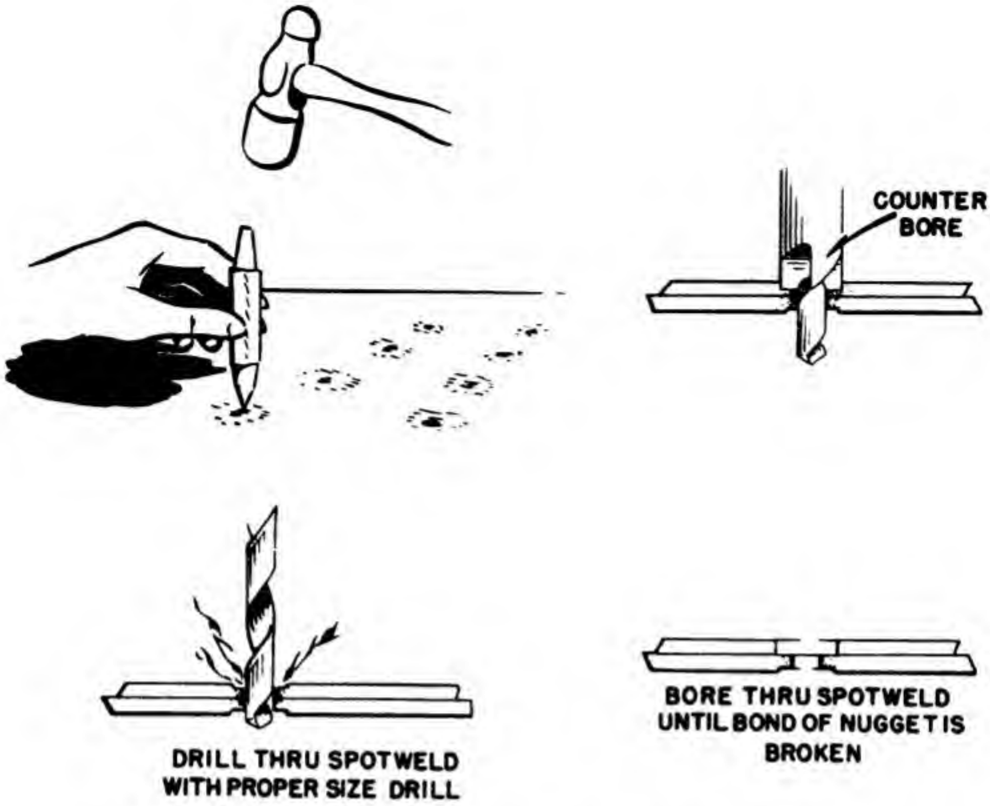


Figure 56.—Removing spot welded skin.

CHAPTER 9

INSPECTION AND REPAIR

CABLES

Preformed, corrosion resisting steel cables used in airplanes, fall into two distinct classes, namely: flexible and extra-flexible.

Chart 79.—Flexible cables (1/16–3/8) preformed

Type	Size	Material	Number of strands	Wire per strand	Permissible broken wires in any 1 inch
Extra flexible	1/8″ and up.	Corrosion resisting steel.	7	19 total (133).	6
Flexible	1/16–3/32	Same	7	7 total (49).	3

NOTES:
1. Replace any worn or corroded cables.
2. The size of a cable is the diameter measurement possible.

INSPECTION.—For number of permissible broken wires in any one inch refer to chart 79. However, if a plane is to be subjected to maneuvers which will place added demands upon the cables, replace even though the cables do not have the permissible number of broken strands. Cable breakage usually occurs in the section of the cable that passes through a fair-lead or over a pulley.

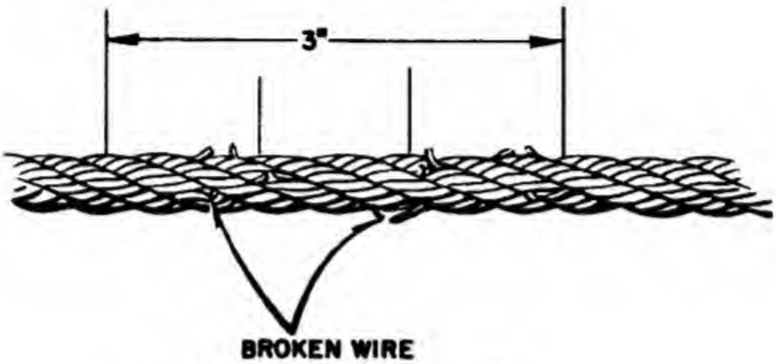


Figure 57.—Negligible damage to 7 × 19 control cable.

RUST PREVENTION.—Tinned steel cables require a rust-preventive. Simoniz Corol No. 95 or AN–C–52 (Paralketone-type I may be used). Refer to chapter 6 for information on application of Paralketone.

CABLE SPLICING

In an emergency, cables $\frac{3}{32}$ inch and larger may be fabricated by substituting bushings and thimbles for the original fittings and woven splice. The wrap soldering method is employed for cables under $\frac{3}{32}$ inch. For fitting selection see chart 80.

NAVY FIVE-TUCK SPLICE

PREPARATION.—Prepare cable and bend thimble points out to approximately 45°. The short end should be approxi-

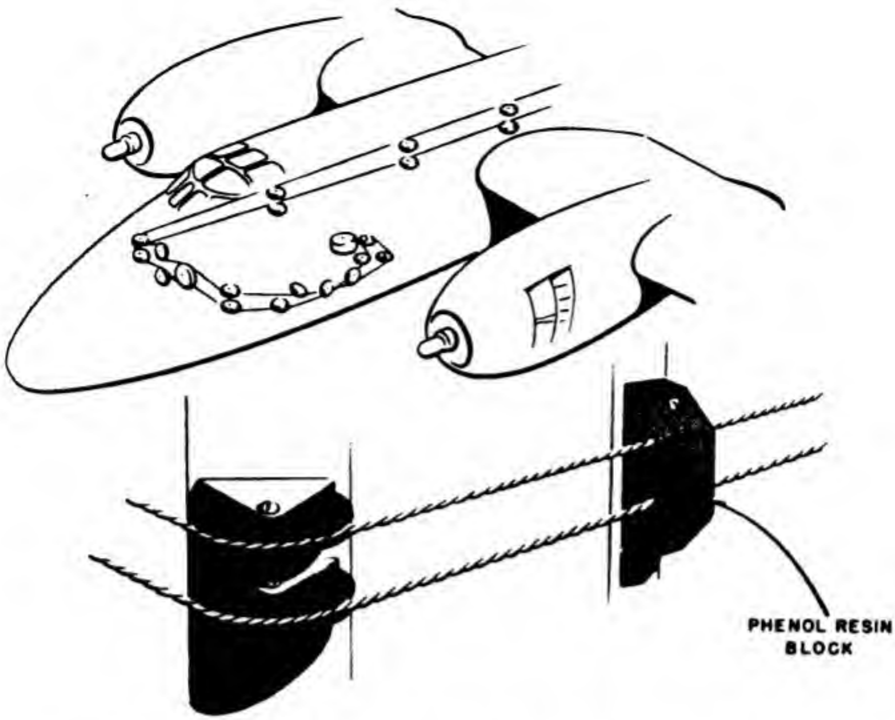


Figure 58.—Pulley and fair-lead with cable going through.

mately 8 inches in length. When cutting cable, cut mechanically, not with a torch. Solder cable end with class A solder, using a stearic acid flux. Soldering is to prevent cable fraying while making splice.

Chart 80.—Cable and fittings

Wrapping wire 48-19			Test load (pounds)		
Cable size	Diameter (inch)	Length (approx. in.)	Cable spec. 48-21	Cable spec. 48-22	Thimble bushings
1/16	0.020	25	300	300	AN-100-3—AN111-3.
3/32	.020	37	700	600	AN-100-3—AN111-3.
1/8	.015	58	1,200	860	AN-100-4—AN111-4.
5/32	.025	82	1,900	1,550	AN-100-5—AN111-5.
3/16	.035	109	2,800	1,900	AN-100-6—AN111-6.
7/32	.025		3,600	2,800	AN-100-7—AN111-7.
1/4	.035	159	4,800	3,500	AN-100-8—AN111-8.
5/16	.050	195	7,500	5,500	AN-100-10—AN111-10.
3/8	.050		10,500		AN-100-12—AN111-12.

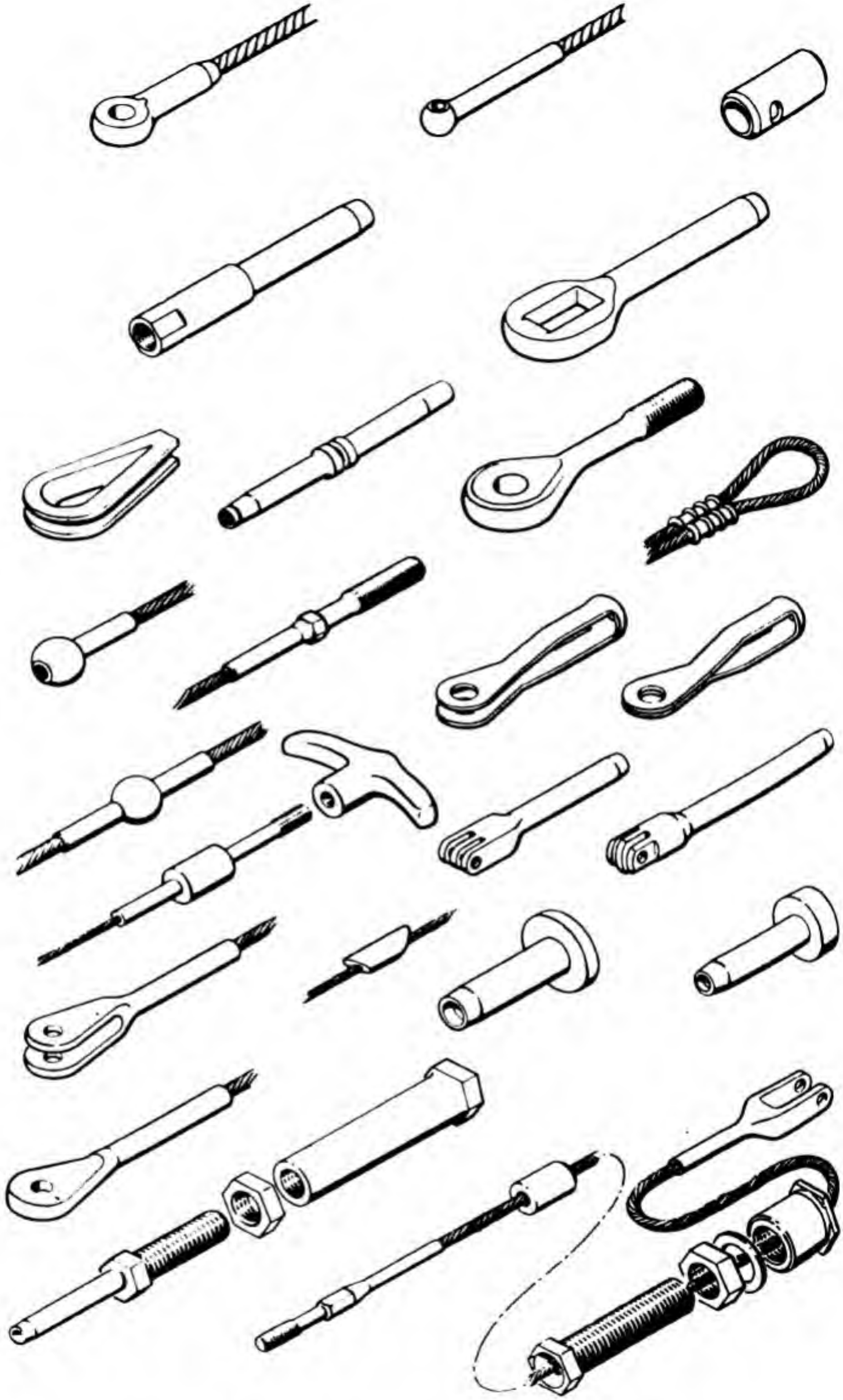


Figure 59.—Cable fittings and swaged terminals.

Chart 81.—Test loads for cable terminal splices

Cable diameter (inch)	Thimble		Flexible cable				Non-flexible cable	
			Spec. AN-RR-C-43		Spec. AN-RR-C-48		Spec. AN-C-76	
	Carbon steel cable	Corrosion resistant steel cable	Proof load	Full strength	Proof load	Full strength	Proof load	Full strength
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1/16	AN100-3	AN100C-3	300	410	300	410	300	475
3/32	AN100-4	AN100C-4	500	780	550	780	700	1, 040
1/8	AN100-4	AN100C-4	1, 200	1, 700	1, 150	1, 610	1, 250	1, 990
5/32	AN100-5	AN100C-5	1, 700	2, 380	1, 550	2, 210	1, 900	3, 040
3/16	AN100-6	AN100C-6	2, 500	3, 570	2, 350	3, 310	2, 750	4, 370
7/32	AN100-7	AN100C-7	3, 350	4, 760	3, 100	4, 420	3, 650	5, 800
1/4	AN100-8	AN100C-8	4, 200	5, 950	3, 950	5, 610	4, 800	7, 600
9/32	AN100-9	AN100C-9	4, 800	6, 800	4, 800	6, 800		
5/16	AN100-10	AN100C-10	5, 900	8, 320	4, 900	6, 960	7, 500	11, 900
3/8	AN100-12	AN100C-12	8, 650	12, 200	7, 200	10, 200	10, 500	16, 600
7/16	AN100-14	AN100C-14	10, 600	15, 000	9, 600	13, 600	14, 100	22, 300
1/2	AN100-16	AN100C-16	13, 700	19, 400	13, 700	19, 400	17, 100	27, 100

PROOF LOADING

The cable and splice should withstand loads indicated in chart 81 for a minimum period of 3 minutes.

FITTINGS AND TURNBUCKLES

Essentially, an assembly as shown in figure 59 makes possible tension adjustment of aircraft cables.

SWAGED, SOLDERED AND WRAP-SOLDERED TERMINALS

SWAGED TERMINAL.—The desired terminal is swaged around the cable end, after first determining cable length and fitting length after swaging.

SWEAT SOLDERED TERMINALS.—The fitting is designed to be sweat soldered. Use only stearic acid and rosin flux.

Caution.—Used to replace only original sweat soldered terminals.

WRAP SOLDERED TERMINALS. Used on 1/16-inch cables and fabricated. Two and one-fourth inches are required for short end. The cable is wrapped with a single layer of copper or brass wire as indicated in the table. Wrapping is followed by sweat soldering, using a tin-lead solder and a stearic acid and rosin flux.

Chart 82.—Wire sizes for wrapping soldered terminal splice

Diameter of cable (inch)	Terminal dimensions (inches)			Serving wire B and S gage
	L ±1/8	D ±1/16	C ±1/16	
1/16	2	9/16	1/8	24
3/32	2 1/2	3/4	1/8	24
1/8	2 7/8	7/8	1/8	24
5/32	3 1/4	1	1/8	24
3/16	3 5/8	1 1/8	1/8	20
7/32	4	1 1/4	1/8	20
1/4	4 1/2	1 3/8	3/16	20
5/16	5 1/4	1 5/8	3/16	20
3/8	6 1/4	1 15/16	1/4	18
7/16	7	2 3/16	1/4	18
1/2	8	2 1/2	1/4	18

PULLEY AND FAIR-LEADS

PULLEYS.—Pulleys used in aircraft control systems are made from a fabric processed to a desirable hardness for cable use. Pulleys are employed primarily to change cable direction.

FAIR-LEADS.—Cables may be deflected as much as 2° if cable tension is under 50 pounds. One degree deflection is permissible with a tension range between 50 and 150 pounds. Above 150 pounds, no deflection by fair-lead is permissible.

SAFETY WIRE

Parts, such as drilled head bolts, fillister-head screws, turnbuckles, thumbscrews, plugs, and the like, are safety-wired with wire, zinc coated, soft steel, Specification No. AN-W-22. Annealed corrosion-resisting wire, Specification No. AN-W-23, Condition A, is also used for specific applications; for example, where non-magnetic qualities and heat-resisting properties are desired.

The size of safety wire used for bolts, screws, plugs, and the like, is determined by the size of the safety wire hole. Approximately 75 percent of the hole should be filled by the wire. Copper wire 0.020-inch maximum diameter should be used for safetying such devices as canopy release handles and similar items. The wire is generally applied by twisting.

Several different methods of safety-wiring turnbuckles are in use, but the standard preferred procedure is shown in figure 60.

When replacement of turnbuckle safety wire is necessary, the procedure shown in figure 60 should be used.

ADJUSTMENT.—Make necessary adjustments of turnbuckle before safety wiring. Maximum threads ± 3 threads with reference to turnbuckle end.

When a swaged terminal is being safetied, one wire shall be passed through the hole provided for this purpose in the terminal, looped over the free end of the other wire and both ends shall be wrapped around the shank as shown in figure 60.

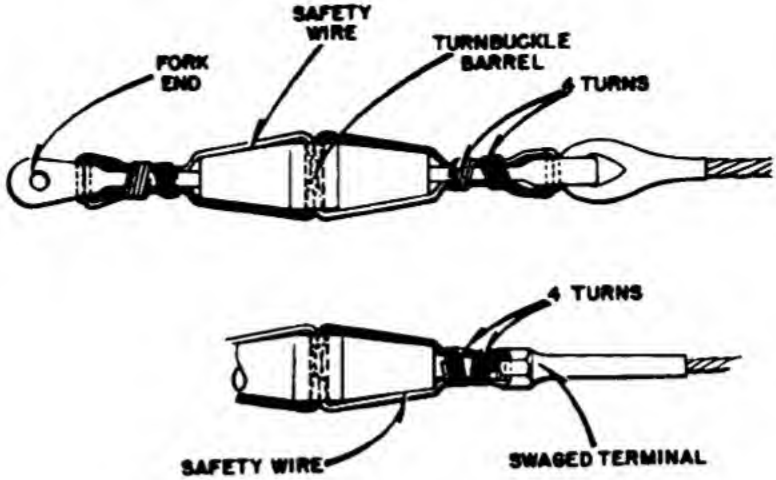


Figure 60.—Safety wiring a turnbuckle.

BONDING

For surfaces to be bonded and bonding requirements, refer to charts 83 and 84.

Chart 83.—Index of objects to be grounded and applicable requirements

Object to be grounded	Designation of requirement applicable to the bond. (See chart 84.)
1. Ailerons	F
2. Ammunition racks	A
3. Anchor and mooring equipment	A
4. Armor plate:	
a. Shock mounted	P
b. Hinged	A
c. For radio and electrical equipment	C
d. For other equipment	A
5. Arresting hooks	G
6. Bomb and torpedo racks:	
a. Internal bomb bay racks	C
b. External racks	C
7. Bomb sight mounting rack	C
8. Bunks	A
9. Conduit (electrical)	M
10. Control cables and rods:	
a. To aileron	L
b. To elevator	L

Chart 83.—Index of objects to be grounded and applicable requirements—Continued

Object to be grounded	Designation of requirement applicable to the bond. (See chart 84.)
10. Control cables and rods—Continued	
c. To rudder	L
d. To flaps and floats	L
e. To engine and engine compartment	A
11. Control sticks and columns (metallic)	A
12. Controls, engine (pilot and engineer):	
a. Throttle	A
b. Carburetor mixture	A
c. Carburetor heat	A
d. Propeller	A
e. Cowl flap	A
f. Wobble pump	A
13. Controls (miscellaneous):	
a. Gun	A
b. Bomb release	A
c. Flare release	A
d. Flap (hand operated)	A
e. Landing gear (hand operated)	A
f. Floats (hand operated)	A
g. Brake	A
h. Trim	A
14. Cowling and nacelles (engine):	
a. Cowl rings (not shock mounted)	D
b. Cowl rings (shock mounted)	D
c. Wrap cowls (with piano hinges)	J
d. Removable cowls (fastener mounted)	J
e. Access doors and inspection plates	J
15. Doors (and inspection plates):	
a. Doors which open in flight into airstream:	
1. Landing gear doors	G
2. Arresting hook doors	G
3. Bomb bay doors (fuselage)	F
4. Bomb bay doors (wing)	F
5. Camera doors	G
6. Bomb sight doors	G
7. Flare doors	G
8. Navigator's hatches	G
9. Roll type bomb bay doors	B
10. Tunnel gun doors	G

Chart 83.—Index of objects to be grounded and applicable requirements—Continued

Object to be grounded	Designation of requirement applicable to the bond. (See chart 84.)
15. Doors (and inspection plates)—Continued	
b. Door normally closed in flight (in airstream):	
1. Access doors to fuel and oil tanks	I
2. Access doors and inspection doors and plates within 3 feet of antennas or lead-ins	I
3. Anchor doors	G
4. Entrance doors	G
5. Escape hatches	G
6. Inspection doors with piano hinges	G, I
7. Inspection plates (without hinges)	G, I
8. Gun loading doors	G
9. Life raft doors and covers	G
10. Loading hatches	G
11. Beaching gear doors	G
c. Doors inside airplane:	
1. Distribution and fuse panel doors	F
2. Flight deck doors (acoustic)	A
3. Locker doors	A
4. Refrigerator doors	A
5. Watertight bulkhead doors	A
16. Elevators	F
17. Electric motor mounts	C
18. Engine shock mounts:	
a. Main engines	D
b. Auxiliary power unit engines	D
19. Flaps:	
a. Landing flaps:	
1. Conventional hinges	F
2. Piano hinges	G
3. Fowler flaps	B
b. Diving flaps:	
1. Conventional hinges	F
2. Piano hinges	G
c. Cowl flaps	R
20. Floats:	
a. Retractable	G
b. Fixed	G
21. Guns (machine guns and cannon)	G

Chart 83.—Index of objects to be grounded and applicable requirements—Continued

Object to be grounded	Designation of requirement applicable to the bond. (See chart 84.)
22. Heaters (cabin):	
a. Electric fan type	C
b. Combustion type	C
c. Other	C
23. Hood (sliding):	
a. Within 3 feet of antennas or lead-in	B, H
b. More than 3 feet from antennas or lead-in	B, G
24. Instrument boards:	
a. Main or pilot's instrument board	E
b. Copilot's instrument board	E
c. Rear seat instrument board	E
d. Bomber's instrument board	E
e. Navigator's instrument board	E
f. Engineer's instrument board	E
g. Other instrument board	E
25. Landing gear (wheel types)	G
26. Lights (external)	G
27. Lines:	
a. Fuel (including vents)	Q
b. Oil and hydraulic (all types)	A
c. Oxygen (all types)	E
d. Heat	A
e. Water	A
f. Anti-icer fluid	E
g. Metallic fittings and couplings in metallic fuel lines	C
h. Metallic fittings and couplings in nonmetallic fuel lines	E
28. Pedals (rudder)	A
29. Radio racks, brackets and shelves	K
30. Radiators:	
a. Oil	C
b. Water	C
31. Rudder	F
32. Seats (adjustable and fixed)	G
33. Stoves and hot plates	E
34. Sinks and wash stands	A
35. Tabs	G
36. Tables (all types)	A

Chart 83.—Index of objects to be grounded and applicable requirements—Continued

Object to be grounded	Designation of requirement applicable to the bond. (See chart 84.)
37. Tanks:	
a. Gas:	
1. Metal	C
2. Rubber (bulletproof) and other nonmetallic	N
3. Droppable (metal)	E
b. Oil	E
c. Water	A
d. Anti-icer fluid	E
38. Toilets (metal)	A
39. Windows (hinged or sliding)	B, G

Chart 84.—List of detail bonding requirements

Designation	Requirement
A	No additional bonding required.
B	Bond, if practicable; keep track unpainted.
C	Construction or installation shall provide suitable bonding (0.0025 ohm) to basic structure and shall include jumper(s), if required.
D	Bond at minimum of four places approximately equally spaced across mounts and supports. The jumpers used shall also meet any power return current capacity requirements.
E	Construction or installation shall provide suitable bonding (0.01 ohm) to basic structure through mounts or supports and shall include bonding jumper(s) if required.
F	Bond across each hinge to basic structure by shortest practicable bonding jumper.
G	No additional bonding required, providing resistance to basic structure through hinges, locking, latching or fastening mechanisms does not exceed .01 ohm.
H	No additional bonding required, providing resistance to basic structure through hinges and locking and latching mechanisms does not exceed 0.0025 ohm at any point of measurement even under operating conditions.

Chart 84.—List of detail bonding requirements—Continued

Designation	Requirement
I	Bond at least once across hinge or from plate to basic structure by shortest practicable bonding jumper when within 3 feet of radio antenna or lead-in or when at gas and oil filler caps, overflow and vent lines, etc.
J	Bond across each piano hinge with shortest practicable jumper. Cowl fasteners shall be provided along each edge of wrap or removable cowl at intervals not exceeding 12 inches.
K	Bonding shall be accomplished by bare, clean metal-to-metal contact of all mounting plate, rack, shelf, bracket, and structure mating surfaces so as to form a continuous, low impedance ground from equipment mounting plates to basic structure. The total resistance from the equipment mounting plate to basic structure shall not exceed 0.0025 ohm. Bonding jumpers shall not be used.
L	Bond at outboard end if resistance to ground exceeds 0.01 ohm.
M	When within 3 feet of radio equipment or lead-in, bond to basic structure every 18 inches, except where practicable positions of supporting and bonding clamps and blocks do not exceed 24 inches. Resistance between clamp and conduit within 3 feet of radio equipment, antenna, or lead-in, shall not exceed 0.0025 ohm. When ahead of firewall, bond to forward side.
N	Bond to basic structure each metallic object entering tank as close to tank as practicable.
P	Bond to basic structure with one bonding jumper unless shock mounts are conductive.
Q	Bond to basic structure each extremity of each section of metallic fuel lines over 2 feet in length; for shorter sections, apply a single bond. When within 3 feet of radio or other electronic equipment, antennas, or lead-ins, the maximum resistance to basic structure shall not exceed 0.001 ohm.
R	Bond by one jumper to basic structure.

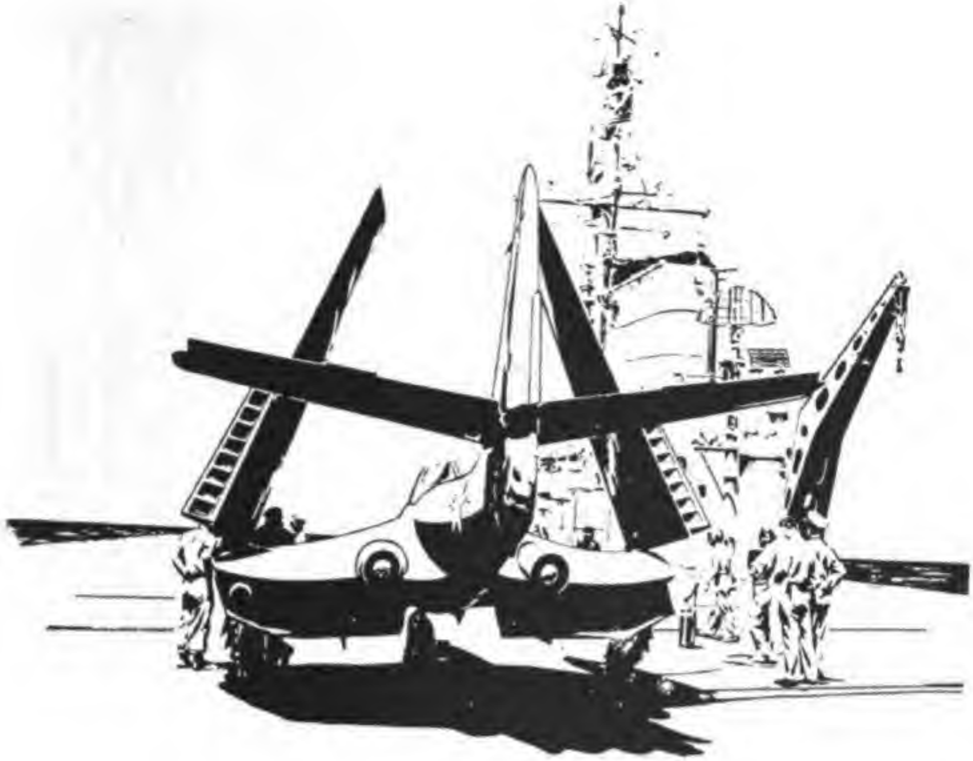
Rigging, in a broad sense, consists of alinement of the aircraft components, balancing and adjustment of controls.

Alinement consists primarily of restoring original measurements, such as wing tip locations. Such mesurements and dimensions are given in the *Erection and Maintenance Manuals* for the plane in question.

Control adjustment incorporates adjustment of primary and secondary control surfaces. Cable tension is checked with a tensiometer as shown in figure 61, and necessary adjustments (turnbuckle) of tension are made in accordance with plane specifications and flight conditions.

Figure 61.—Tensiometer.

Control surface travel adjustments (up throw, down throw or rudder throw), are made by several different methods, such as using measurement or special instruments.



CHAPTER 10

NONMETALLIC MATERIALS

AIRCRAFT FABRICS

Aircraft fabric is usually woven from a nap and fuzz free, 60-strand, 2-ply yarn, with an 80 to 84 thread count per inch. The terminology used to distinguish the cross and lengthwise threads is *woof* and *warp*, respectively.

This cloth must have a minimum of 80 pounds tensile strength per inch, crosswise or lengthwise. During the weaving process to retain the absorbency of the material, sizing and starches are not used.

Such fabric is available in widths of 36 inches, 42 inches, 60 inches, and 69 inches. The most popular width is 36 inches.

KNOTS

SQUARE KNOT.—Figure 64 illustrates fabrication, locking, and practical application of the square knot.

Chart 85.—Materials used in aircraft fabric repair

Material	Use	Yarn size	Threads per inch	Tensile strength (min)	Normal wt.
Airplane fabric [1, 3]	Covering for all airfoils.	60 2-ply warp and fill.	80–84 in both warp and fill.	80 lb/in. in warp and fill.	4.5 oz/sq yd.
Surface tape [3]	Over lacing cord and reinforcing tape.	60 2-ply warp and fill.	80–84 in both warp and fill.	80 lb/in. in warp and fill.	4.5 oz/sq yd.
Reinforcing tape [2, 3]	Over fabric on rib cap.	Variable	14 warp 24 fill	150 lb. full width.	
Machine thread [3]	All machine sewing	20 4-ply		5 pounds	5,000 yd/lb.
Machine thread		16 4-ply 12 4-ply.			
Hand-sewing thread [3]	All hand sewing	8 4-ply		14 pounds	1,650 yd/lb.
Lacing cord [3]	Lacing fabric to airfoil structure.	20/3/3/3		85 pounds double.	550 yd/lb.
Lacing cord waxed and braided.[3]	Lacing fabric to airfoil structure.	Optional	16 ends, 3 ply in braid.	80 pounds double.	310 yd/lb.

[1] Linen is also satisfactory for patching tears and holes in cotton fabric surfaces.
[2] A narrower and lighter grade of commercial tape may be substituted where a continuous support is used in place of stitching.
[3] Cotton fiber.

Chart 86.—Threads and tape

Type	Twist	Material	Ply	Size	Tensile strength	Remarks
Hand-sewing thread	L. H.	Unbleached cotton.	4 strands	No. 8	9 lbs	
	L. H.	Unbleached linen.	3 strands	No. 30	9 lbs	
Machine sewing thread	L. H.	Unbleached cotton.	4 ply	16–20	4–5 lbs	
Rib-stitching cord, Navy linen.	L. H.	Unbleached linen.	9 strands			No wax.
AAF		Cotton	3 ply	16		Waxed when received.
Reinforcing tape				¼–1¼″	Heavy Strong	Used under rib stitching.
Surface tape						Over rib lacing and tape
Wax		Beeswax				Pull cord over block 4 times and after every 6th stitch.

Chart 87.—Stitches

Method	Type	Stitch per in.	Edge distance	Distance between stitches	No. of stitch rows	Remarks
Machine sewed	301 lockstitch	8–10	1/16	1/4″–3/8″	2	Chordwise if possible.
Hand	Baseball	4 (min.)				Fold fabric edges under 1/2″. Lockstitch every 6″.

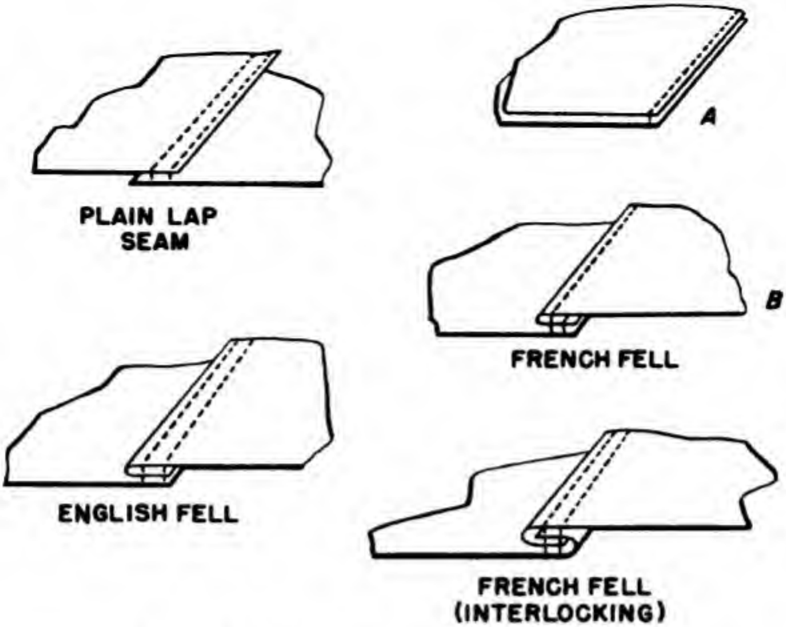


Figure 62.—Machine-sewed seams.

SPLICE KNOT.—If it becomes necessary to tie two rib lacing cords together, they must be tied in such a manner as to cause the knot (splice) to fall between the airfoil surfaces.

Figure 63.—Baseball stitch requirements.

MODIFIED SEINE KNOT.—A modified seine knot is located and tied as illustrated in figure 66.

HALF HITCH.—The loose ends of a knot are usually secured with a half hitch as noted in figure 64.

Chart 88.—Seams

Type seam to use	Location and use of seams
LSc-2	Inside—Not at edges.
LSb-2 SSg-2	Wing closing. Tail surfaces.
LSa-2 (Plain !ap)	In place of type LSc-2 if joining selvages.

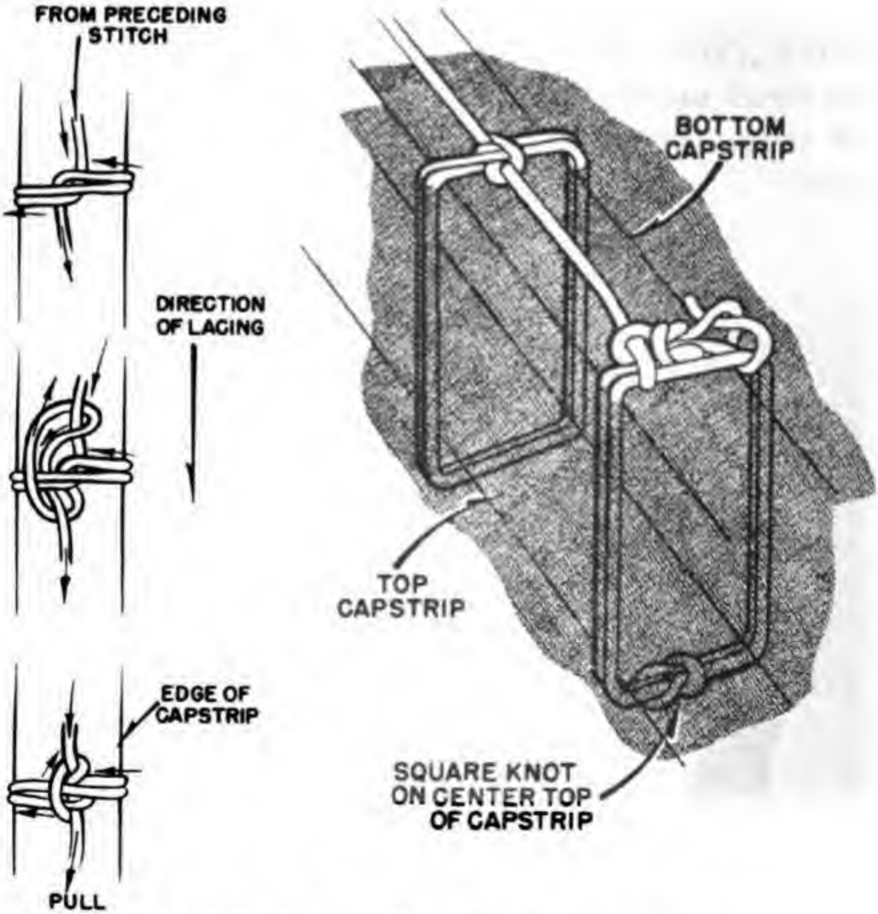


Figure 64.—Starting stitch for rib lacing.

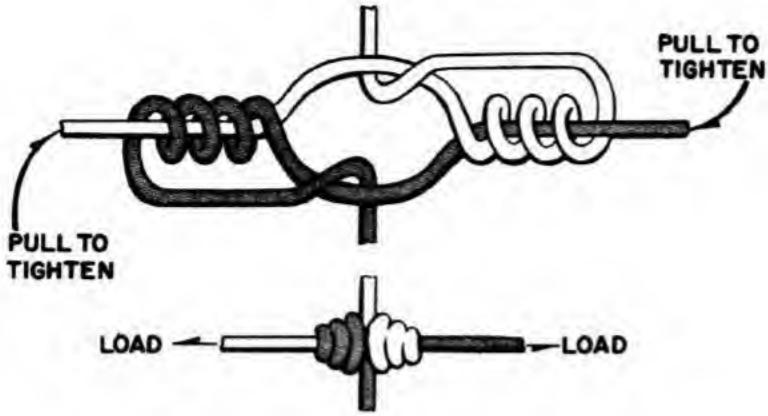


Figure 65.—Splice knot.

Figure 66.—Standard knot for rib lacing.

COVERING AIRFOILS

BLANKET METHOD.—The airfoil is wrapped with airplane fabric (warp-spanwise) and pinned together at the trailing edge. The excess fabric is trimmed off at such length as to allow for ½-inch turn-under. Sewing is accomplished with a baseball stitch.

ENVELOPE METHOD.—Wrap as in the blanket method and make layout. Remove fabric and machine sew as much of the seam as practical leaving the largest end open. With seam on inside of cover, slip the fabric covering over the structure in such a manner as to cause it to locate itself along the trailing edge. Finish the sewing with a baseball stitch.

REINFORCING PATCHES AND DRAIN GROMMETS

CHAFE PATCHES.—Essentially a piece of leather sandwiched between two pieces of fabric and doped to areas subject to wear by control cables or other similar moving parts.

REINFORCING PATCHES.—Openings in fabric for fittings are strengthened by reinforcing patches. The canvas is sewed to the airplane fabric patch and then secured to the airfoil by doping prior to the second coat.

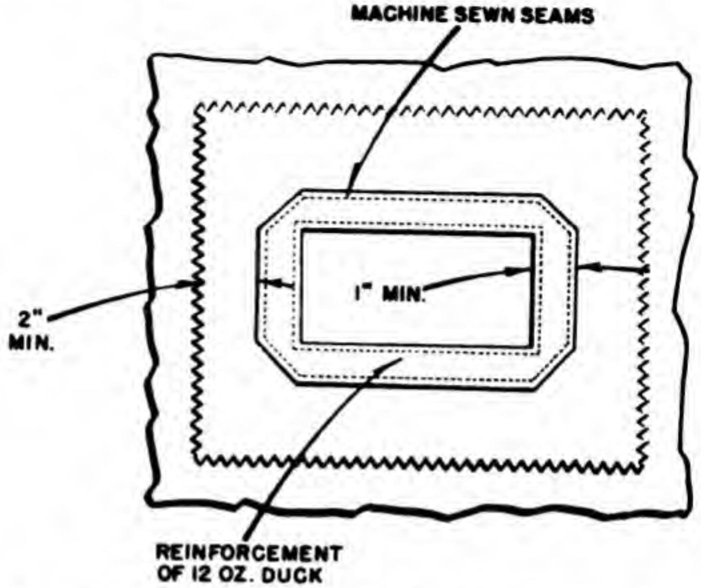


Figure 67.—Reinforcing patch for fitting openings.

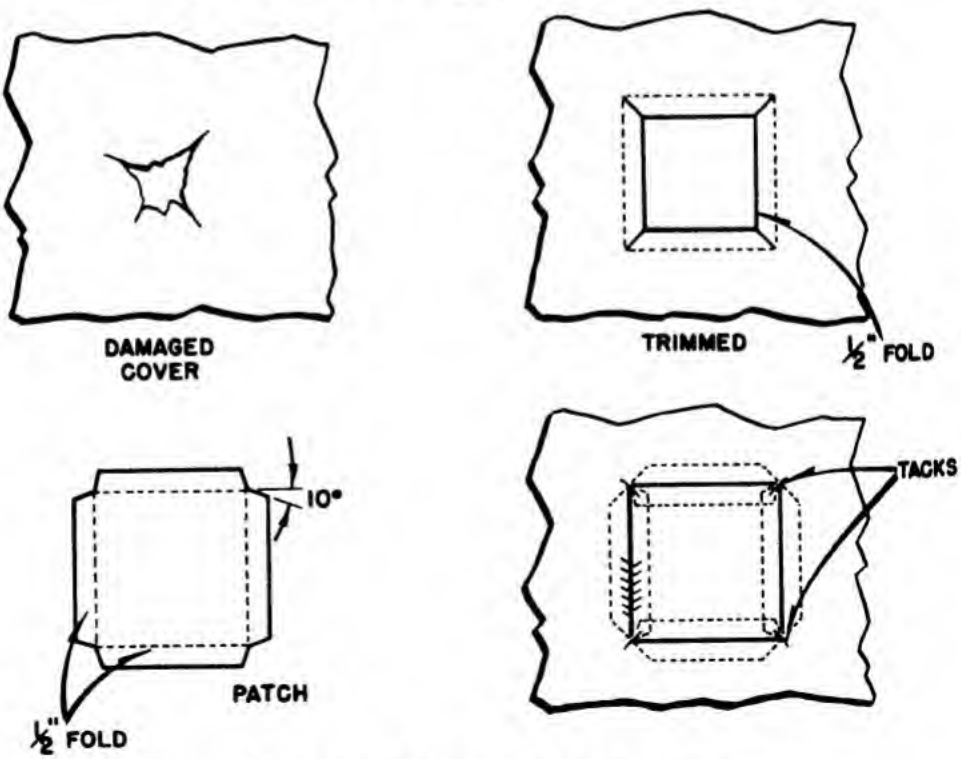


Figure 68.—Fabric repair by insertion.

FABRIC INSPECTION.—Doped aircraft fabrics may be inspected and tested for serviceability by means of a penetrating cone fabric tester in accordance with Technical Note 22–48.

DRAIN GROMMETS.—Plastic or special metal drain grommets are installed (usually with dope) on the underneath side of the trailing edge to provide an outlet for moisture that may collect within the airfoil.

Figure 69.—Doped patch.

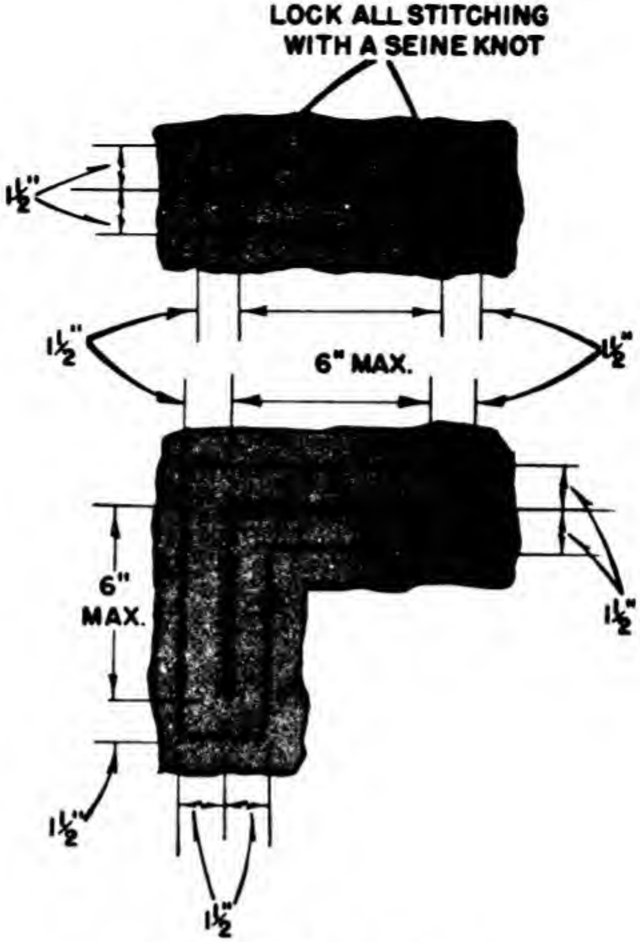


Figure 70.—Repair of tears.

Chart 89.—Number of coats

Coats	Dope	Weight (oz. per sq. yd.)	Remarks
No. 1, 2, 3, 4	Clear	2. 5–3. 5	Coat No. 1—fungicidal ANC–121. Brush—even and smooth. Drying time—30 min. to 1 hr. Coats No. 3 and 4 may be sprayed.
No. 5, 6	Pigmented	4–5	Sprayed, drying time—30 min. to 1 hr.

After coat No. 2 and before last coat to be sprayed, sand lightly (7/10 waterproof sandpaper).

Chart 90.—Dopes and thinners

DOPE

Use	Specification	Material
Base coats	D-34	Dope, fungicidal, cellulose acetate butyrate.
	AN-D-1	Clear dope, cellulose acetate butyrate.
Insignia and finish coats.	AN-D-2 AN-D-3	Dope, pigmented gloss and camouflage, cellulose acetate butyrate.
Pigment for aluminum	AN-TT-A-461	Aircraft, aluminum-pigment-paste.
Emergency pigmented	AN-L-21 AN-L-29	Camouflage and cellulose nitrate-lacquer.

THINNER

To thin dope-cellulose acetate butyrate.	AN-T-27	Cellulose acetate butyrate dope thinner.
	AN-T-28	Cellulose acetate butyrate dope, blush-retarding.

TRANSPARENT PLASTICS

Transparent plastics in aircraft use today fall into two groups, cellulose acetate base plastics and acrylate base plastics. Chart 91 draws a comparison between them. Care must be exercised in properly identifying the original and replacement or repair material.

PLASTIC REPAIRS

Repaired plastic areas must be replaced because of the loss of vision. Repairs are effected only as an emergency measure. The following illustrations indicate recommended methods of repair.

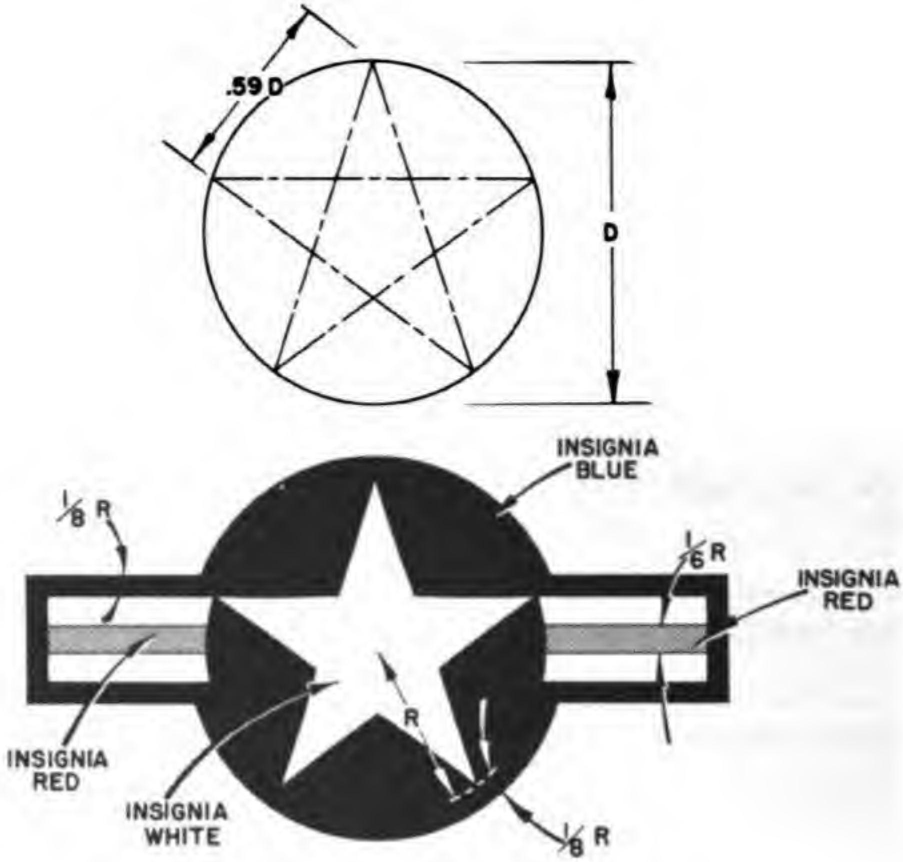


Figure 71.—Detail of wing insignia.

Chart 91.—Plastics used in Aircraft

Type	Identification by comparison	Used in
Cellulose acetate	Relatively dark, may have slightly bluish cast.	Trainers, gliders and observation aircraft.
Acrylate	Increased transparency, appears colorless.	Combat cargo.

Chart 92.—Operation common to acrylic plastic repair

Operation	Agent	Remarks
Sanding	Wet or dry 360A, 400A, 500A, and 600A.	Use wet. Start with coarse 360A circular motion—follow by buffing.
Buffing	Tallow	2,000 r. p. m. Follow with waxing.
Waxing	Soft cloth	By hand usually.
Drilling	Conventional drills.	70° lip angle, 4°–8° lip clearance. Slow feed—use soap solution lubricant.
Removing masking tape.	Naphtha	Dampen paper—wash with soapy water and rinse. (Distilled water.)
Hand tapping	Coarse threads	Large holes—lubricant. (See drilling.) Small holes—under 3/16 inch. No lubricant necessary.
Forming	Oven heat	220° F. Exercise care to prevent "mark off" and finger prints.
Soaking	Cement. (See chart C.)	Soak approximately 15 minutes for fusion of edges.
Masking	Adhesive paper	Prevents cement from contacting areas other than joint.
Cutting	Scribe	Up to (approx.) 0.080, scribe line and thin break.

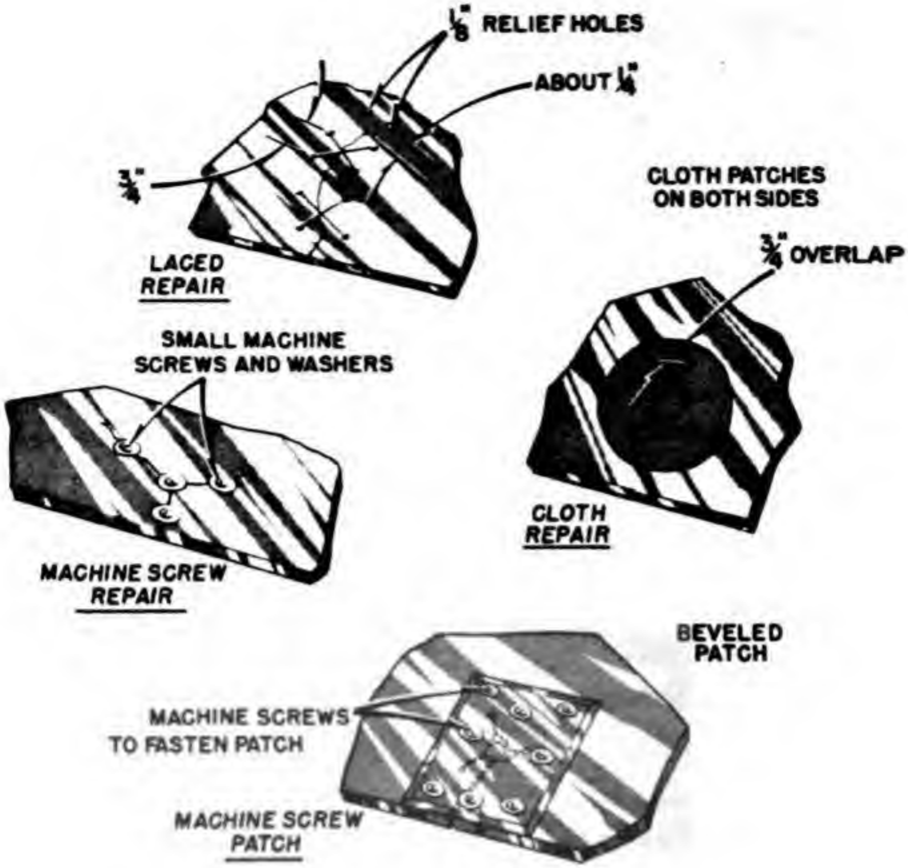


Figure 72.—Emergency methods of repairing.

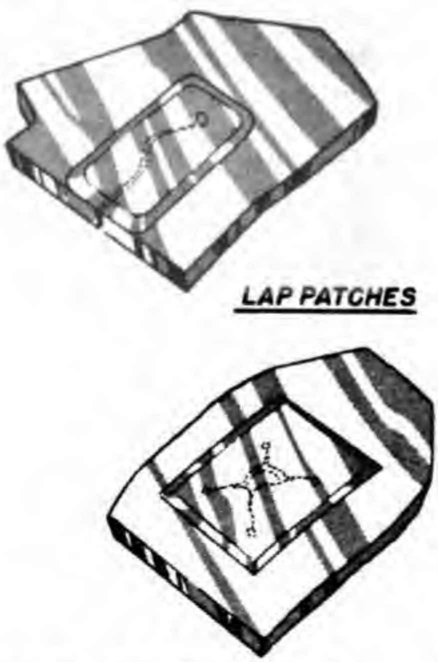


Figure 73.—Semipermanent lap patch.

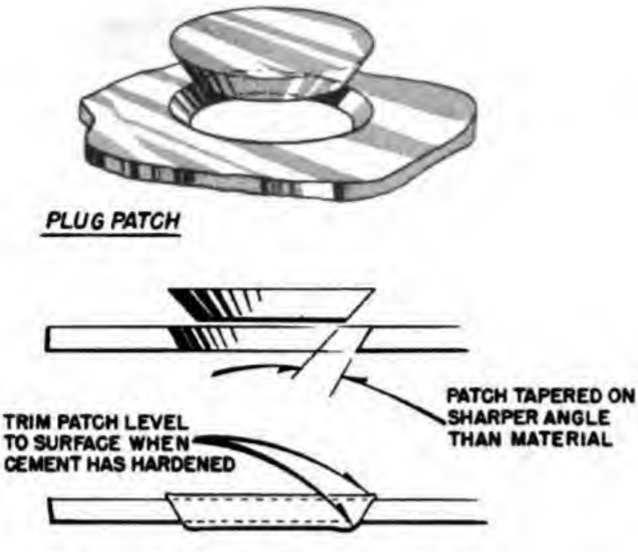


Figure 74.—Semipermanent plug patch.

CEMENTED FABRIC PATCH.—For emergency use only; used to reinforce broken areas until replacement can be made. The fabric (strong) may be bonded to surface with clear lacquer, rubber cement, or acetate dope.

CEMENTS FOR PLASTICS

Cementing of plastic parts is based upon the action of solvent on the plastic surfaces to be joined, forming a cushion. When the two surfaces are pressed together, they unite (intermingle) and cohesion exists as in the original material. Types and effects of various cements are given in chart 93.

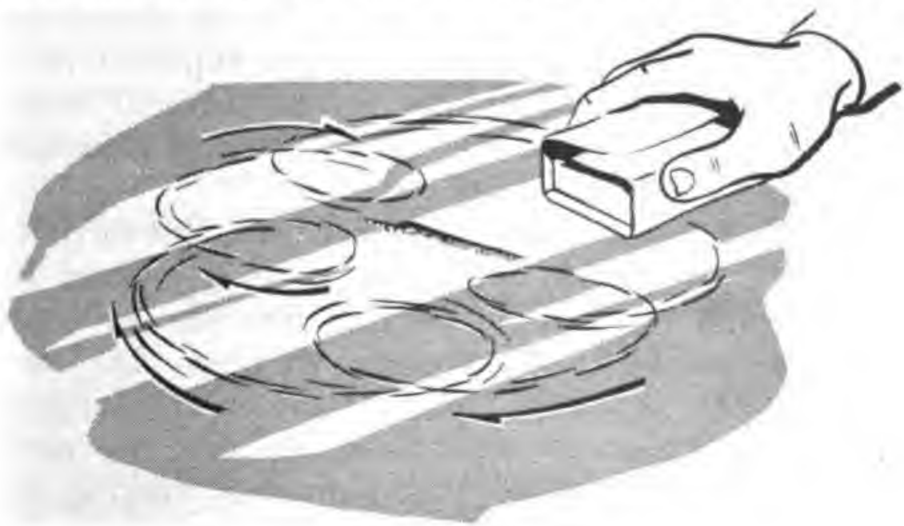


Figure 75.—Sanding plastics.

Chart 93.—Cements for acrylates

Cement type	Catalyst	Remarks
II	Benzoyl peroxide.	Toxic.
Methylene dichloride		Substitute for I–A and H–94 more active, blushes.
Monomeric methyl methacrylate (monomer).		Cushioning less than I–A, crazes.
Glacial acetic acid		Emergency use only, corrosive, wear rubber gloves to handle, will irritate eyes and skin.
Acetone		Emergency use only. Inflammable.

SELF-SEALING FUEL CELL REPAIRS

The purpose of any fuel cell repair is to put the cell back into service with as much as possible of its original ability and capacity to carry fuel or oil. Temporary repairs have proved futile, hence repairs on self-sealing fuel cells should be of the permanent type.

A self-sealing fuel cell is *self-sealing but not self-healing*—therefore, any fuel cell which has been ruptured so that gasoline is in contact with the sealant material must be repaired as soon as possible, with 72 hours as a maximum time limit.

Vapors from aircraft fuel, rubber cement, and solvent are dangerously toxic, even if inhaled for only a short time. Before work is begun, drain the fuel from the cell and dry at low pressure, using a compressed air hose. Do not use an electric fan as sparks from the motor are dangerous. When it is necessary to work inside the cell, two persons should be assigned the job. An individual working inside the tank must wear a rescue breather. The second workman

should be in such a position outside the cell that he may observe any sign of distress shown by the person inside the cell.

In using permanent repair methods, it is necessary to know the type of inner-liner material used in the cell construction. There are four general types: (1) Buna N, (2) thiokol, (3) neoprene, and (4) royalin.

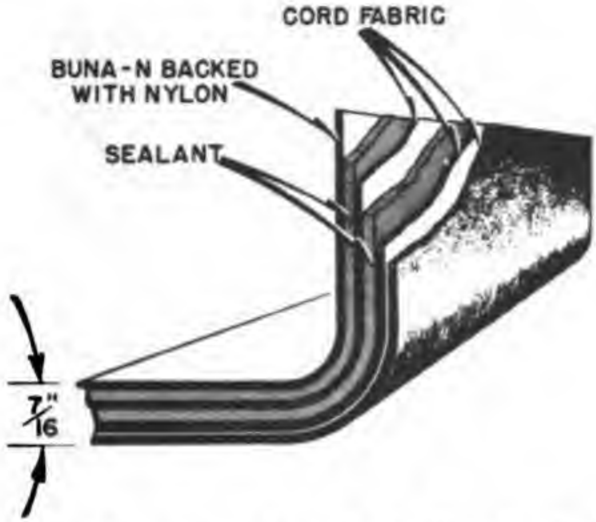


Figure 76.—Construction of standard self-sealing fuel cell.

Tools and equipment necessary for repairs include an air drill, extra emery buffing sleeve, stitcher (⅛-in.), roller (¼-in.), mill knife, shoe knife, paint brush (1-in.), shears (6- to 10-in.), emery cloth, safety light, stainless-steel mirror, 12-inch dividers, ruler, clean rags, and Holland cloth.

A knowledge of paints, solvents, and precautions to be used with them, as well as detailed methods of making all types of self-sealing fuel cell repairs may be found in the latest revision of NavAer 03–10–513.

REPAIR TOOLS AND MATERIALS

TOOLS.—The necessary tools needed for cell repair, are listed below:

8–10 inch shears	12-inch rule.
¼-inch stitcher	Emery sleeve mandrel (1 × 1).

Gooseneck stitcher (1/32″)	Rotary files (1 × 1) (1 × 2).
Skiving knife	Pneumatic buffer.
8-inch divider	Mill knife.
Cement cup	Vapor proof light.
Cement brush	White chalk.
Inspection mirror	Safety solvent can, clean rags.

Figure 77.—Fuel cell repair tools.

Chart 94.—Rubber repair materials

Material	Use
Cement—J868	Requires accelerator (1½ teaspoon to 1 pt. of cement) sealant repairs.
J868 solvent—Methyl ethyl ketone	To clean surfaces (buffed).
Ethyl acetate (Mek)	To reactivate cement.
EC678–S	Innerliner repair.
EC678–S Solvent—methyl isobutyl ketone (Mik).	Reactivator.
Nylon sandwich	Inside repair of Buna N.
Square woven fabric	Outside fuel cell repair.
Emery cloth No. 40 and No. 80	Buffing.

PREPARATION AND APPLICATION OF RUBBER CEMENT

PREPARATION.—After cement has been thoroughly stirred, it should have a consistency approximating that of number 20 motor oil. Solvent is used as a thinning agent if thinning is necessary.

APPLICATION.—After all buffing and cleaning of the area to be repaired, and the patch to be used has been completed, two coats of prepared cement are applied to each with a brush. The first coat should be permitted to dry thoroughly. The second coat should dry to a tacky condition before applying the prepared patch.

REPAIR OPERATIONS

BUFFING.—Areas to be repaired are carefully buffed to roughen to surface in order to assume better anchorage of the patch. The necessary buffing has been done if the surface has taken on a smooth dull appearance or until some cords are partially exposed evenly over the buffed area.

BEVELING.—All patches are beveled to make for better edge adhesion.

FEATHERING.—In repairs involving two patches, the underneath patch is feathered as illustrated in figure 78*A*.

STITCHING.—A patch is stitched into place (rolled down) as outlined in figure 78*B*. The location of the repair determines the stitcher size that may be used.

PERMANENT TYPE REPAIRS

CORNER REPAIR.—A corner repair requires an internal and external patch. Injuries over two inches are not repaired.

BLISTER REPAIR.—Blisters are located by raised areas on the inner liner. When such injury exists, repair the inner liner by patching as shown in figure 79.

MINOR SLIT-TYPE REPAIR.—An injury (slit-type) under 2 inches is repaired by applying an inside patch (nylon sandwich) and an outside patch (square woven fabric).

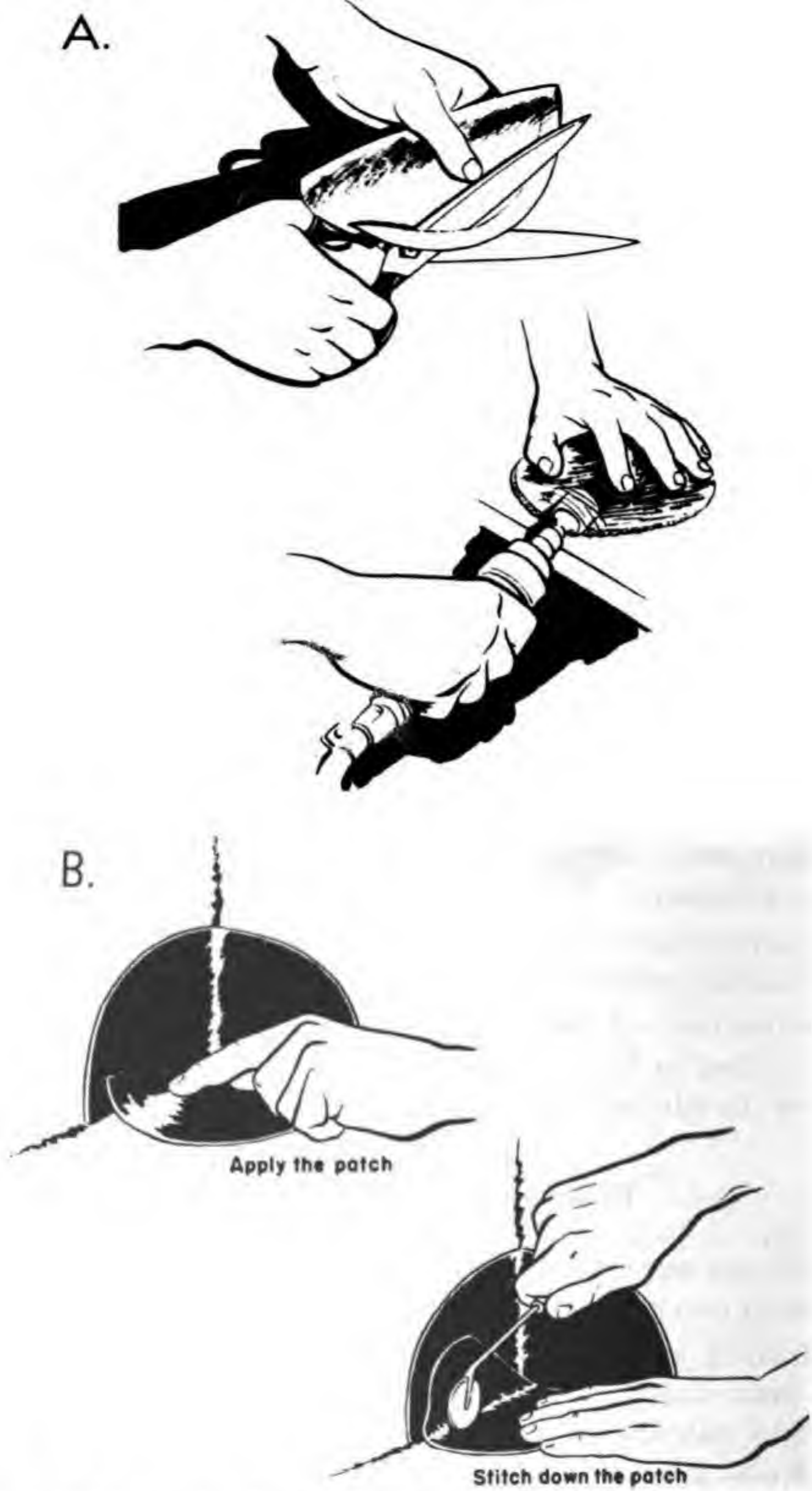


Figure 78.—Feathering and stitching (A) Beveling and feathering a patch, (B) Stitching down a patch.

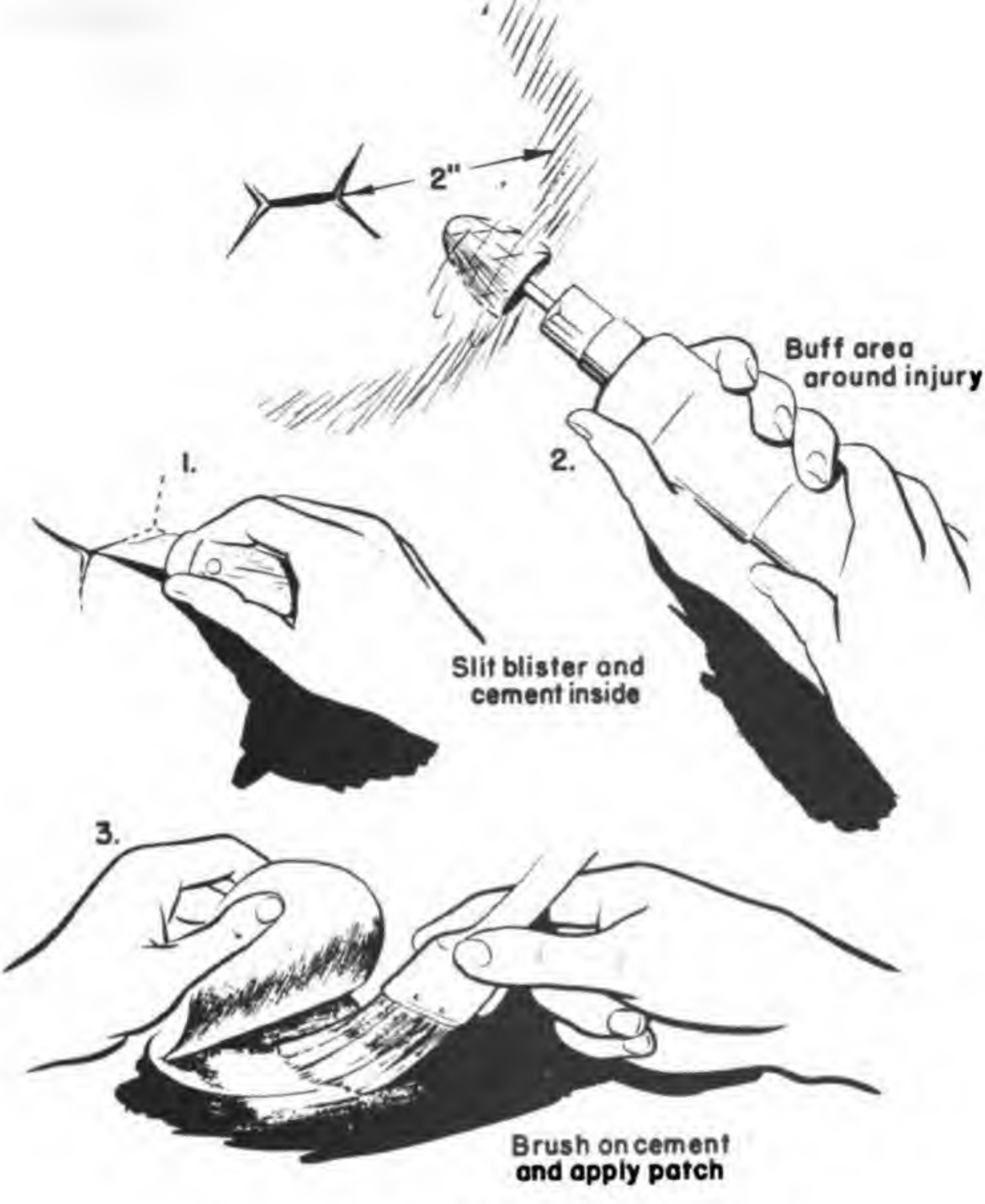


Figure 79.—Blister repair.

Major Slit-type repair.—An injury (slit-type) ranging from 2 inches to 10 inches; the repair is accomplished as outlined for a minor slit-type repair.

REMOVAL AND REPLACEMENT OF FITTINGS

Removal.—Strip off the finishing collar with pliers to give access to the fitting flange. It may be necessary to use solvent to loosen cement. In a similar manner loosen the outside flange back to the center of the fitting. Then cut off the fitting, including flange, level with the surface of the cell

wall. The next step is to cut the core out, but do not increase the size of the original opening.

INSTALLATION.—Thin cell wall by buffing down the inside flange until new fitting fits properly. After the new fitting has been fitted, buff cell wall areas around the fitting according to chart 96. Also, buff both flanges of the new fitting (inside and out) and feather edges. Cement as a patch and apply the necessary cover patches indicated in chart 96.

FUEL CELL REMOVAL AND INSTALLATION

Fuel cells should be removed as outlined in the *Structural Repair Manual* for particular airplanes in question.

AIRCRAFT TIRES

LINE INSPECTION.—Tires that are known to have hit on an object should be removed and given a thorough inspection for possible internal breaks before the next flight.

A daily check should be made of inflation pressure with an accurate gage. Tires found to be losing an excessive amount of air, after checking valve core for possible leakage, should be removed and completely inspected. Refer to applicable aircraft E & M manuals for recommended inflation pressures.

Aircraft tires can be recapped when the tread rubber has been worn off in service. Recapping has proven both practical and economical.

Over- and under-inflation are dangers that should be avoided because it causes faster and uneven wear.

A tire showing evidence of camber wear should be turned around on the same wheel and used until the tread design first starts to disappear. In this way, a tire will give added service by wearing over the entire tread surface.

PREVENTING NYLON FLAT SPOTTING.—New nylon tires are subject to stretching during the first 24 hours that they are under inflation pressures. New tires, subjected during this 24-hour stretching period to a plane's weight, may become flattened and out-of-round. To prevent such a condition inflate tire after mounting to the required pressure and place in a horizontal position for 24 hours before installation.

REMOVING FLAT SPOTS FROM TIRES.—

1. Change the position of flat spot to upper half of casing.
2. Increase by 50 percent the normal air pressure for 30 minutes.
3. Deflate tire to the normal air pressure.
4. Repeat steps 1, 2 and 3 if flat spot remains.

STORAGE.—The life of a tire or tube is directly affected by storage conditions. Listed below are rules to be followed.

1. Storage room should be clean, cool, dry, dark and away from electrical equipment. Tires must be kept free of grease or other petroleum products (removed by washing with vegetable oil soap and water).
2. Place tires upright in racks so designed that the tire will not become creased. Racks should not be close to steam pipes.
3. Use original containers for new tube storage.
4. Deflate and roll up used tubes before storing.
   Caution.—Sharp creases are to be avoided.
5. Tires put in storage first should be issued first.

Chart 95.—Aircraft tire and tube types

Type I	Smooth contour.
Type II	High pressure.
Type III	Low pressure.
Type IV	Extra low pressure.
Type VI	Low profile.
Type VII	Extra high pressure.

Chart 96.—Fuel cell repair—buffing areas and patch size

Types of repairs	Buffing area		Patch sizes			
			Inside		Outside	
	Inside	Outside	First patch	Second patch	First patch	Second patch
Fitting	2½'' beyond flange.	2½'' beyond flange.	Edge of core 1'' off flange.	Edge of core 2'' off flange.	Edge of core 2'' off flange.	None.
Flow tube	2½'' beyond flange.	2½'' beyond flange.	Edge of core 1'' off flange.	⅛'' on tube 2'' off flange.	⅛'' from core opening; 2'' off flange.	None.
Minor (under 2'').	2½'' beyond injury.	3'' beyond injury.	2'' beyond injury.	None	2½'' beyond injury.	None.
Major (over 2'').	3½'' beyond injury.	4'' beyond injury.	2'' beyond injury.	3'' beyond injury.	2½'' beyond injury.	None.
Corner	2½'' beyond injury.	3'' beyond injury.	1'' beyond injury.	2'' beyond injury.	2½'' beyond injury.	2½'' diameter.

Blister	2½″ beyond injury.	None	2″ beyond injury.	None	None	None.
Seam	2½″ beyond injury.	None	2″ beyond injury.	None	None	None.
Standard build-up	2½″ beyond injury.	5″ beyond injury.	1″ around injury.	2″ around injury.	2½″ beyond sealant.	3½″ beyond sealant.
Plioform build-up.	2½″ beyond injury.	6″ beyond injury.	1″ beyond injury.	2″ beyond injury.	2½″ beyond sealant.	3½″ beyond sealant.

CHAPTER 11

OXYACETYLENE AND ARC WELDING

BRAZING

Unlike metals, such as cast iron and steel, stainless steel and copper, and other combinations of like or unlike metals may be bonded together by brazing.

Brazing rods—Brazing rods have as their main alloys copper and zinc and are available in grades A, B, C, and D.

Flux—Borax and boric acid (50/50) is used to braze bronze, monel, copper or brass. When brazing steel, use a flux containing 75 percent boric acid to one part borax. Apply to joint by heating rod and dipping in flux. After job is completed, excess flux may be removed with an acid solution dip (5 percent nitric acid) and a cool water rinse.

Preparation of parts—Clean joint until surface is bright and free of grease or oil.

Brazing temperature—Brazing temperature (neutral flame) is indicated when the brazing material (rod) begins to flow into the joint.

Chart 97.—Chemical requirements, melting points, and typical uses of silver solder

Chemical composition				Melting point ° F.	Flow point ° F.	Color	Uses and characteristics
Class [1]	Silver range %	Copper range %	Zinc range %				
0	19. 0–21. 0	44. 0–46. 0	33. 0–37. 0	1, 430	1, 500	Yellow	Used for ordinary brazing requiring a solder with higher physical properties than brazing (spelter) solders, providing appearance or use is such as not to require solder with a high silver content.
1	44. 0–46. 0	29. 0–31. 0	23. 0–27. 0	1, 250	1, 370	Nearly white	Used for general silver soldering.
2	64. 0–66. 0	19. 0–21. 0	13. 0–17. 0	1, 280	1, 325	White	A high silver content solder, used only when high strength, good appearance and resistance to corrosion is required.
[2] 3	14. 5–15. 5	79. 0–81. 0		1, 200	1, 300	Gray-white	Used only to braze copper and alloys with a copper base. Not to be used on ferrous alloys.

[3] 4	49. 0–51. 0	14. 5–16. 5	14. 5–18. 5	1, 160	1, 175	Yellow-white	General purpose, used to braze brass, copper, nickel-copper alloys, alloy steels and ferrous metals.
[4] 5	49. 0–51. 0	14. 5–16. 5	13. 5–17. 5	1, 195	1, 270	Yellow-white	Used for the same purposes as class 4 and 6 if a fillet is required. Also for such hard materials as used for tools (cemented carbides).
[5] 6	49. 0–51. 0	14. 5–16. 5	23. 0–27. 0	1, 166	1, 190	Yellow-white	Same as class 4.

[1] Total other elements 0.15%.
[2] Phosphorous range 4.75 to 5.25%.
[3] Cadmium range 17.0 to 19.0%.
[4] Cadmium range 15.0 to 17.0%; nickel range 2.50 to 3.5%.
[5] Cadmium range 9.0 to 11.0%.

SILVER SOLDERING

Monel metals, silver, nickel, copper and copper alloys may be silver soldered. For chemical requirements, melting points and typical uses refer to chart 97.

SILVER BRAZING FLUX.—A paste form. The flux, in a thin paste form (thin with water if necessary), is spread with a brush only in the areas to be penetrated by the silver brazing alloy, after the parts have been thoroughly cleaned and the joints closely fitted.

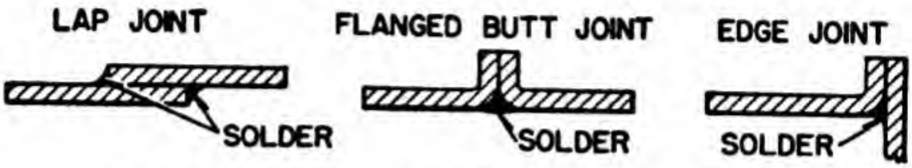


Figure 80.—Recommended joints for silver soldering.

BRAZING.—Use an oxyacetylene flame (neutral or slightly carburizing) as a source of heat. The soldering temperature is indicated by the melting and flowing of the flux. (**Caution.**—Overheated flux disintegrates. Remove flux from finished work by scrubbing in hot water.)

GAS WELDING SAFETY PRECAUTIONS

OXYGEN CYLINDERS.—

1. To prevent an explosion, oxygen under pressure must be kept from coming in contact with oil or grease.
2. Oxygen cylinders should be stored separately.
3. Keep oxygen cylinders protected from the sun, radiators, furnaces, etc., to prevent excessive expansion of gas, creating high tank pressure.
4. Flames of all types must be kept from cylinder.
5. Do not drop oxygen cylinders.
6. Release the oxygen through a regulator.
7. Do not hammer or use wrenches to open the cylinder valves.

ACETYLENE CYLINDERS.—

1. Do not expose cylinder to fire. (Acetylene will burn.)
2. The valve should always be up.
3. Handle cylinders carefully.

4. Do not use a leaky cylinder.
5. When acetylene cylinder pressure reaches 25 pounds, it is considered empty—stop using.

WHILE WELDING.—

1. Keep torch valve closed when not in use.
2. Maintain equipment in good working condition.
3. Do not permit flame to come in contact with the welding equipment.
4. Do not open cylinder valve with pressure regulator open to receive gas.
5. Acetylene gas should not be used at a pressure in excess of 15 pounds.
6. Acetylene and oxygen gas should not be permitted to mix except in a torch.
7. Examine welding jobs for possibility of explosion.

Chart 98.—Characteristics of acetylene and oxygen cylinders and hose used for welding

CYLINDERS

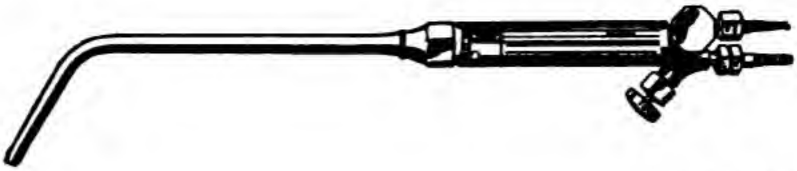
Gas	Type	Capacity (cu. ft.)	Color
*Acetylene	Seamless	100 & 300	Top-blue, remainder black.
Oxygen	Seamless	110-250	Top-green, remainder black.

HOSE

Acetylene	Special, non-porous.		Red, left-hand thread nut ground.
Oxygen	Special, non-porous.		Green or black, right-hand thread.

***Caution.**—Unstable at pressures over 15 lbs. per sq. in. unless dissolved in acetone.

EQUAL PRESSURE TORCH.—An equal pressure torch sometimes referred to as a balanced pressure torch receives an equal volume of both gases (oxygen and acetylene) under the same pressure. The flow of oxygen and acetylene into the torch can be regulated by their respective needle valves.



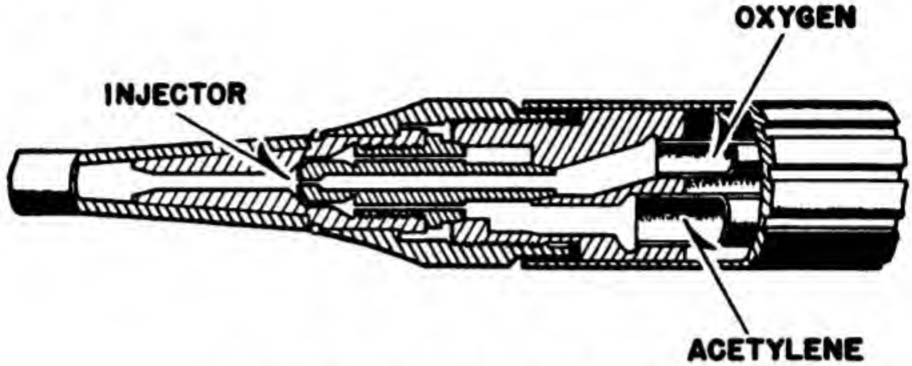


Figure 81.—Equal pressure torch.

Chart 99.—Tip size for various metal thicknesses

Thickness of metal	Division of orifice tips	Pressure per square inch	
		Oxygen	Acetylene
24–22 gage	0. 025	1	1
20–18 gage	. 035	1	1
16–14 gage	. 055	2	2
12–10 gage	. 065	3	3
⅛–$^{3}/_{16}$-inch	. 075	4	4
¼-inch	. 085	5	5

Chart 100.—Tip sizes for welding sheet aluminum (equal pressure torch)

Metal thickness (inch)	Size of tip (number)	Acetylene pressure (pounds)	Oxygen pressure (pounds)
Up to 0.025	0	1	1
0.025–0.050	1	1	1
0.050–0.0625	2	2	2
0.064–0.093	3	3	3
0.093–0.125	4	4	4
0.125–0.1562	5	5	5

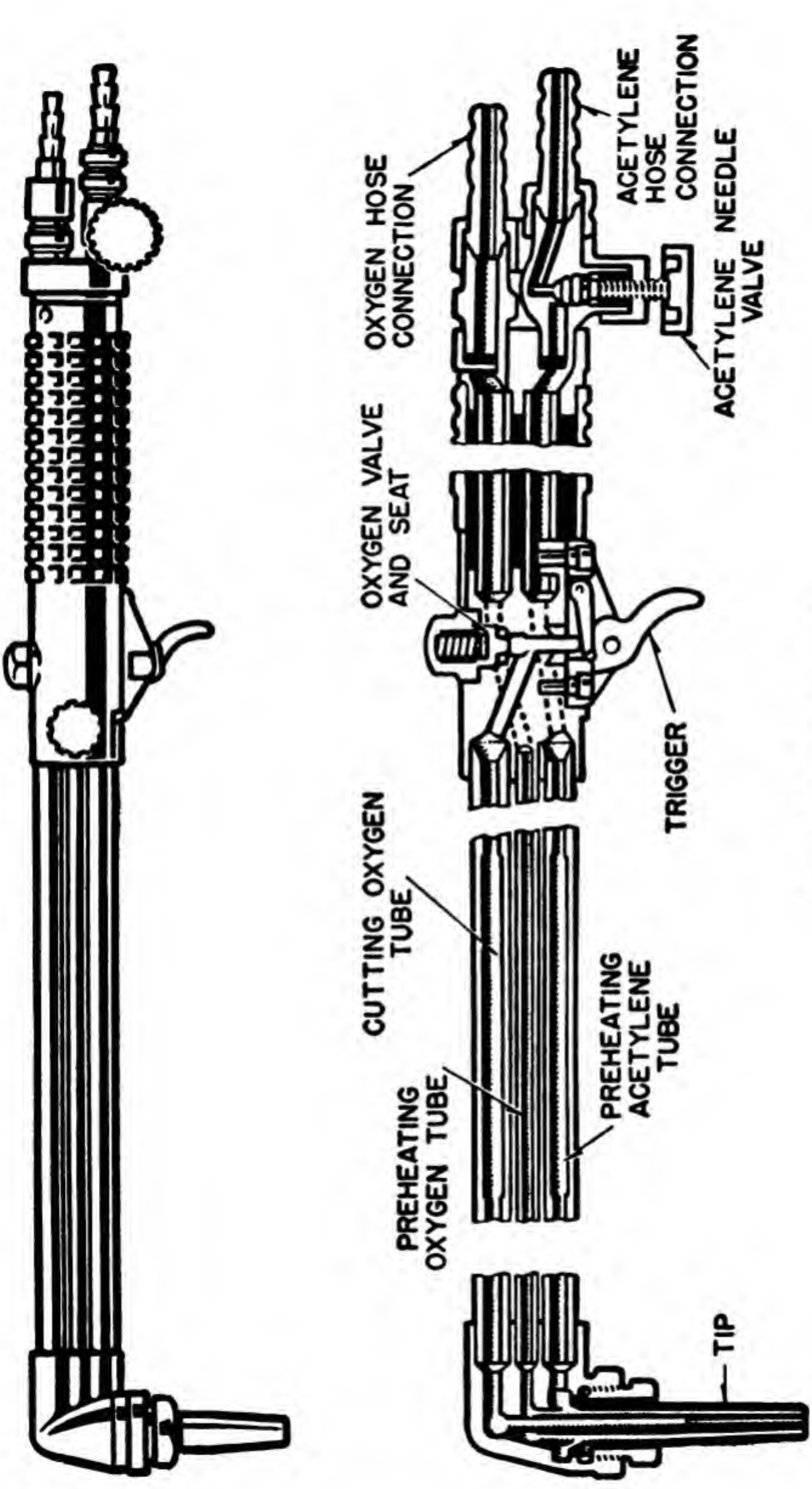


Figure 82.—Cutting torch.

Chart 101.—Tip size for magnesium welding

Tip diameter (inches)	Metal thickness (inches)
0.025–0.040	Below 0.050.
0.035–0.050	0.050–0.080.
0.045–0.060	0.080–0.125.
0.055–0.070	0.125–0.250.
0.065–0.080	0.250–0.500.
0.075–0.090	Over 0.500.

Chart 102.—Cutting torch tip sizes

Tip no.	Thickness of metal (inches)	Acetylene pressure (pounds)	Oxygen pressure (pounds)
1	⅛	4	10
1	¼	4	15
1	⅜	4	20
1	½	4	25
2	¾	5	30
2	1	5	40
2	1½	5	50
2	2	5	60
3	3	6	70
3	4	6	80
3	5	6	90
4	6	7	100
4	8	7	130
4	10	8	150

Chart 103.—Selection of welding rods for metal thickness

Rod diameter (inch)	Metal thickness (ferrous) (inch)
1/16	Up to 1/16.
3/32	1/16–⅛.
⅛	⅛–3/16.
5/32	3/16–¼.
3/16	¼–⅜.

LOW PRESSURE TORCH (INJECTOR).—A torch which uses a 20 to 1 gas pressure ratio of oxygen to acetylene. The torch is intended for use where the acetylene is produced by low-pressure generators.

OXYACETYLENE CUTTING TORCH.—A torch designed to cut metal by rapid oxidation.

CAST IRON RODS.—Gray cast iron may be welded by using a cast iron rod.

Chart 104.—Aluminum welding rods

Use rod	To weld
2S	2S or 3S.
43S	52S or 61S.

Chart 105.—Welding rod sizes for sheet aluminum

Thickness of metal (inch)	Diameter of welding rod (inch)
Up to 0.028	1/16
0.028–0.0625	3/32
0.0625–0.120	1/8
0.120–0.250	3/16

ALUMINUM AND STAINLESS STEEL WELDING FLUX

ALUMINUM FLUX.—A powder flux, from which a thin paste is made by adding water, is applied to the surfaces and welding rod with a brush.

STAINLESS STEEL FLUX.—Powder form reduced to a paste with water and applied by brushing.

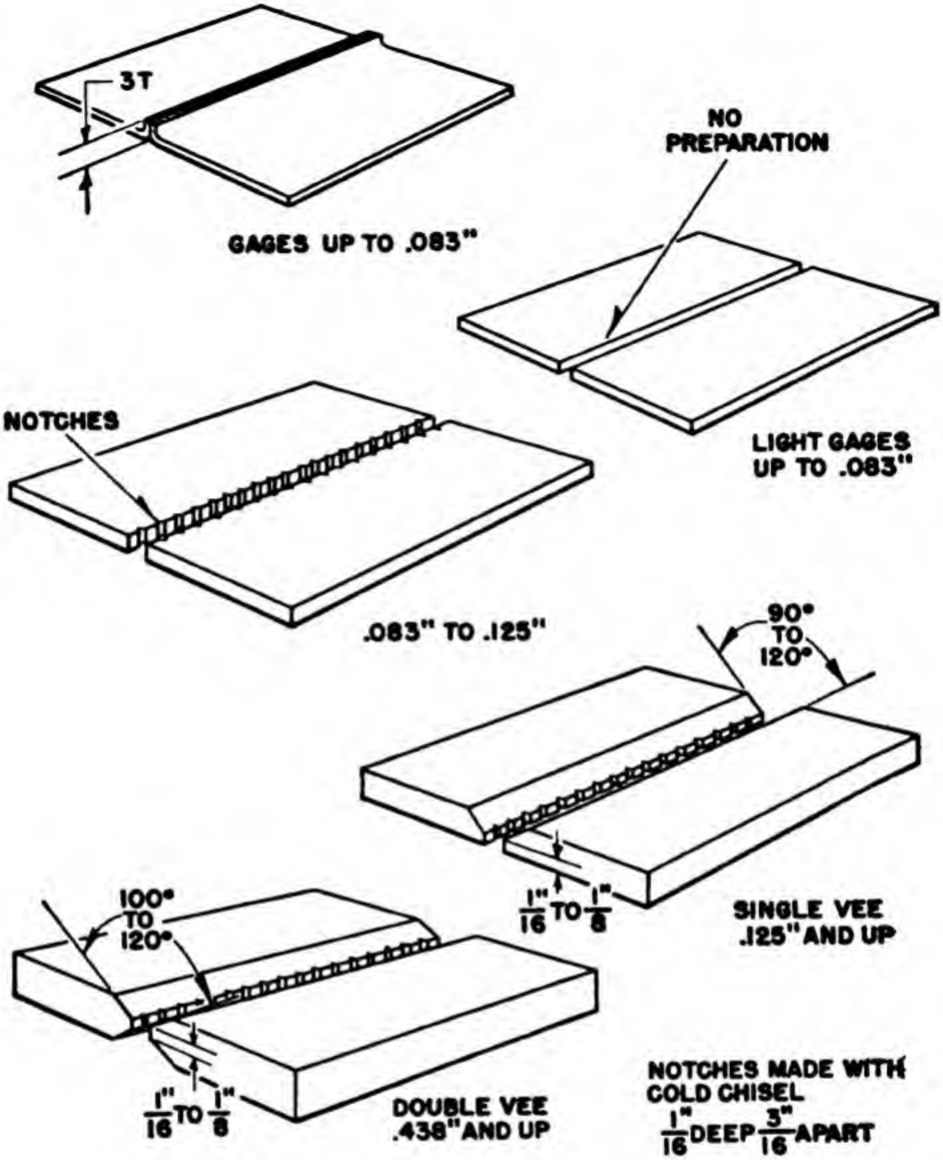


Figure 83.—Butt joints for aluminum welding.

Chart 106.—Filler rod for magnesium alloy welding

Rod size (inch)	American Magnesium Co. alloys (mazlo)	Dow Chemical mag. alloys (dowmetal)
1/8, 5/32, 3/16, 1/4	AM3S	M
1/8, 5/32, 3/16, 1/4	AM-C52S	FS-1
1/8, 5/32, 3/16, 1/4	AM-C57S	J-1
3/16, 5/16	AM88S	

Chart 107.—Selection of welding rod for magnesium

Rod diameter (inch)	Metal thickness (inch)
⅛	Up to 0.060.
5/32	0.050–0.110.
3/16	0.100–0.220.
¼	0.200–0.400.
5/16	0.300 inch or more.

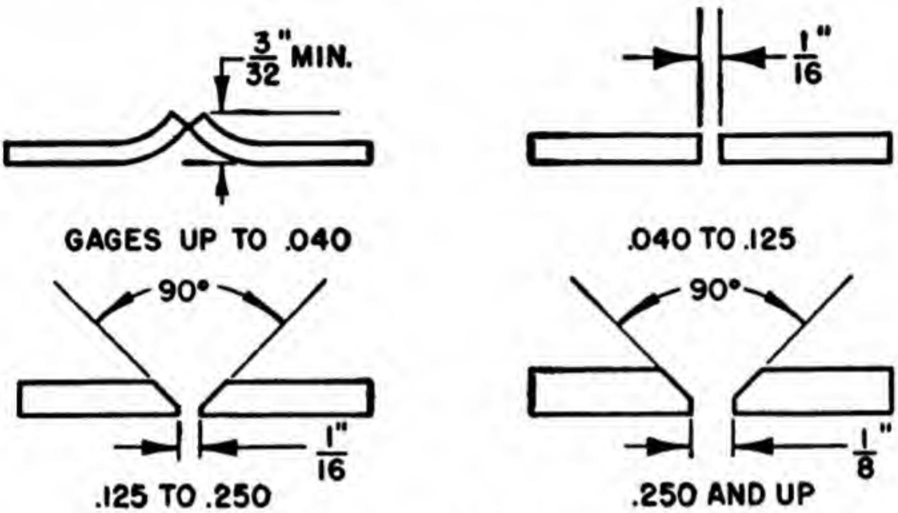
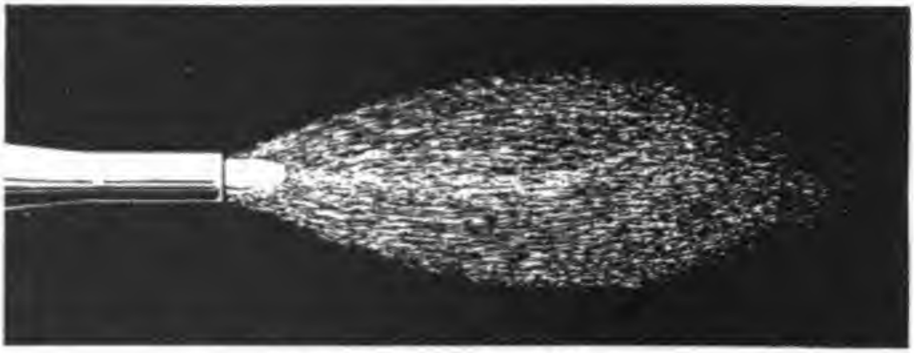


Figure 84.—Butt joints in sheet magnesium.

Chart 108.—Oxyacetylene flames

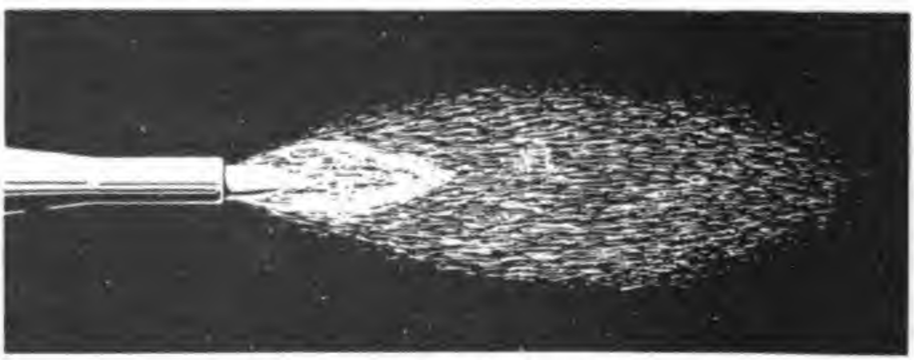
Flame	Approximate temperature (° F.)	Remarks
Carburizing	5, 700	Nickel alloys, monel and inconel.
Neutral	5, 850	General welding, aluminum, magnesium.
Oxidizing	6, 300	Brass.

CARBURIZING FLAME.—A carburizing flame results when a flame has an excess of acetylene.



NEUTRAL FLAME
BALANCED MIXTURE. Brilliant white cone surrounded by larger "envelope flame" of pale blue color.

OXIDIZING FLAME
EXCESSIVE OXYGEN. Similar to neutral flame; shorter, neck-in, and acquires a purplish tinge.



CARBURIZING FLAME
EXCESSIVE ACETYLENE. Three distinct zones. Brilliant white inner cone, whitish intermediate cone, and bluish outer envelope.

Figure 85.—Types of welding flames.

Oxidizing flame.—An oxidizing flame is one receiving an excess of oxygen.

Neutral flame.—A flame using oxygen and acetylene in equal amounts.

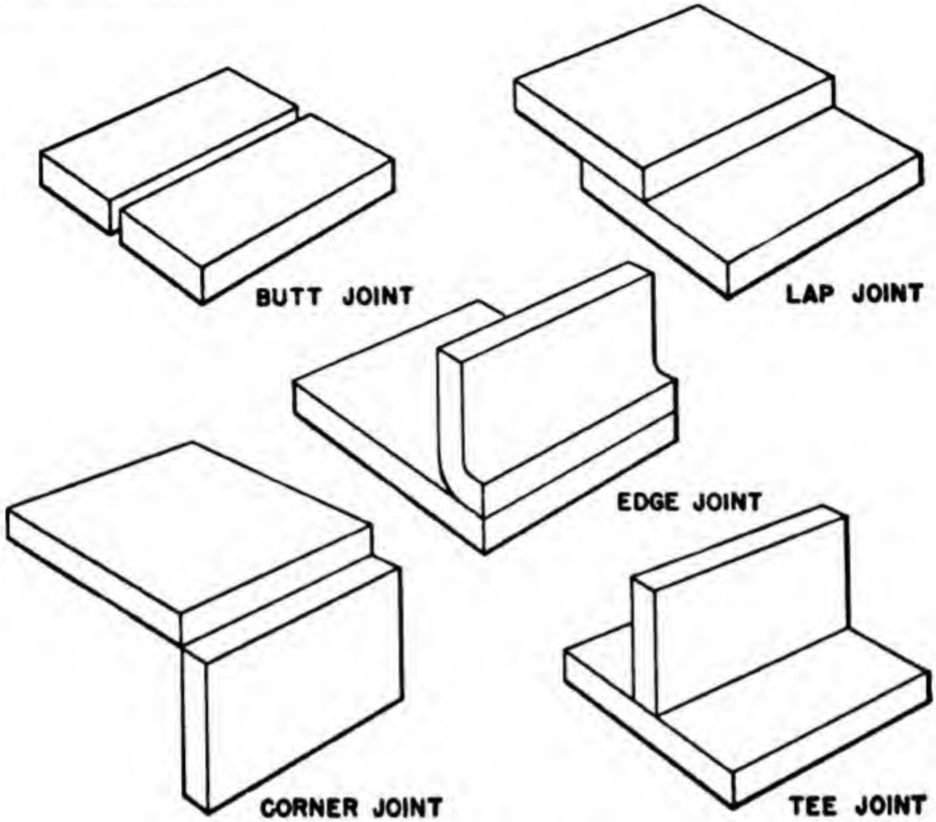


Figure 86.—Joint variations.

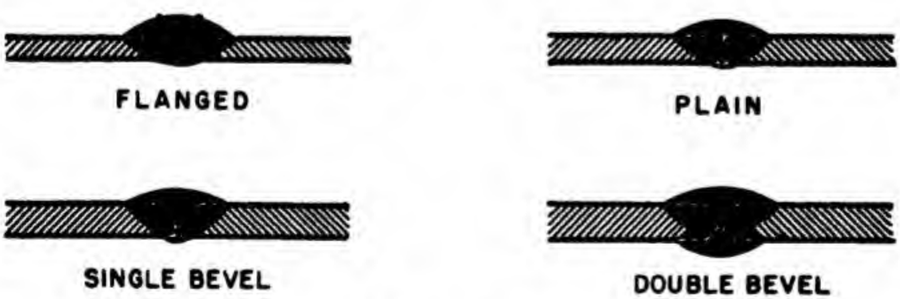


Figure 87.—Butt joints.

Figure 88.—Lap joints.

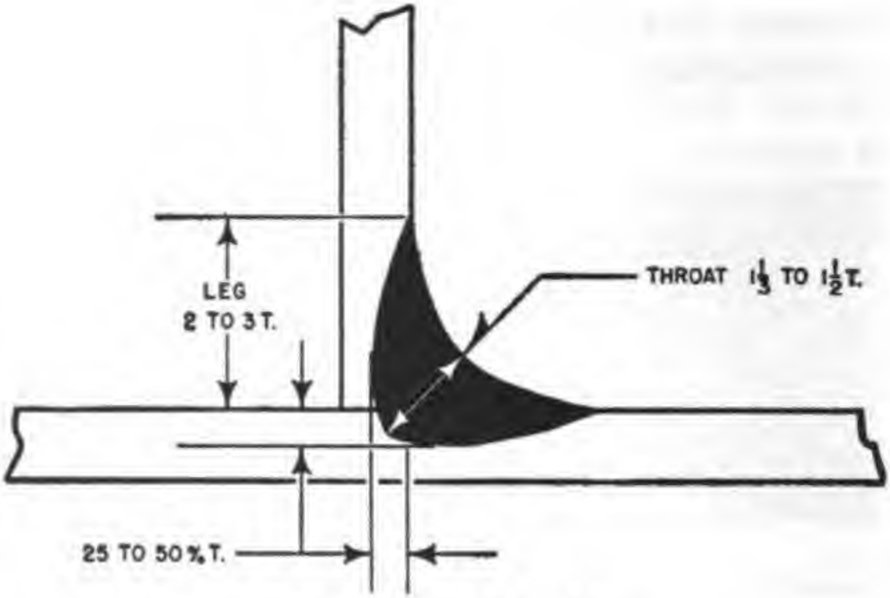


Figure 89.—Fillet weld.

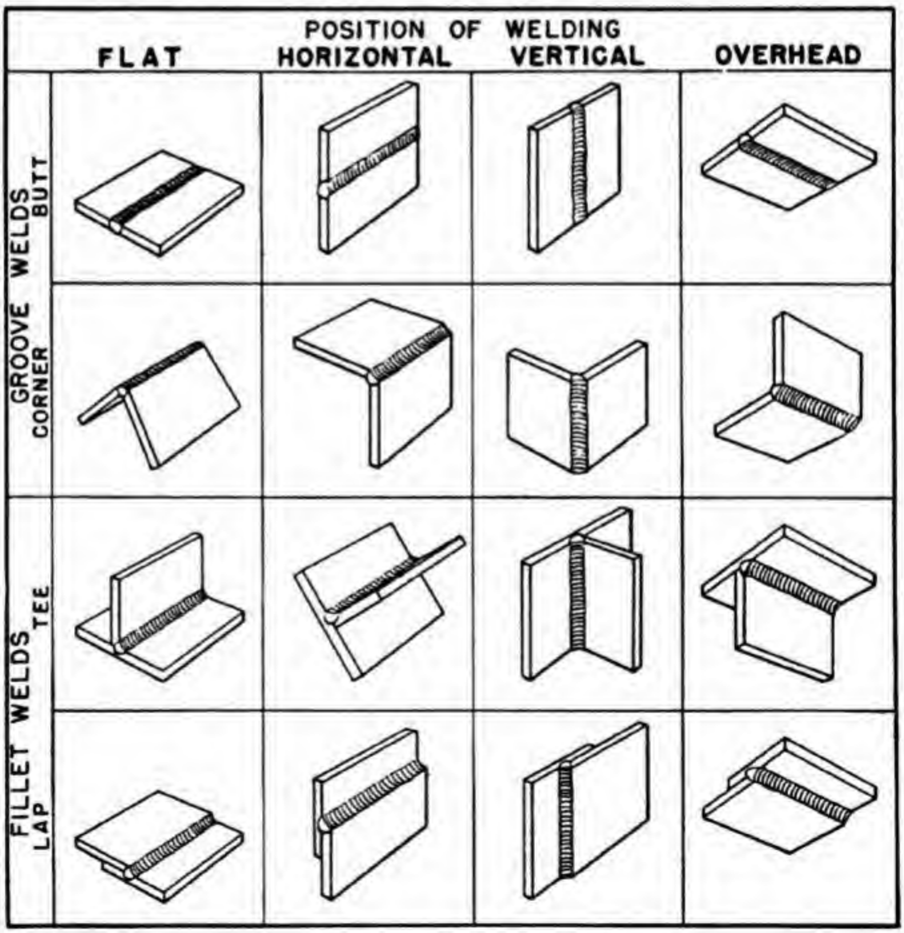


Figure 90.—Welding positions.

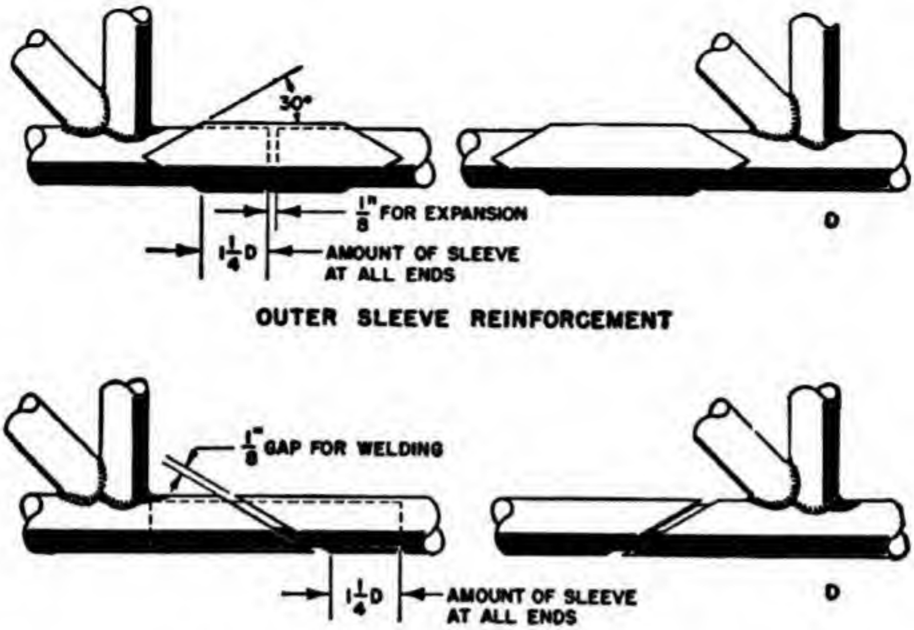


Figure 91.—Inner and outer sleeve splice.

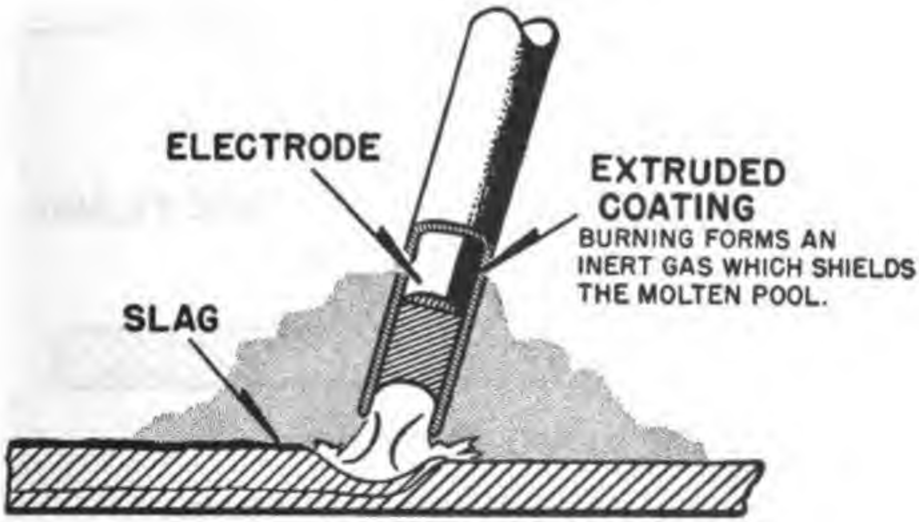
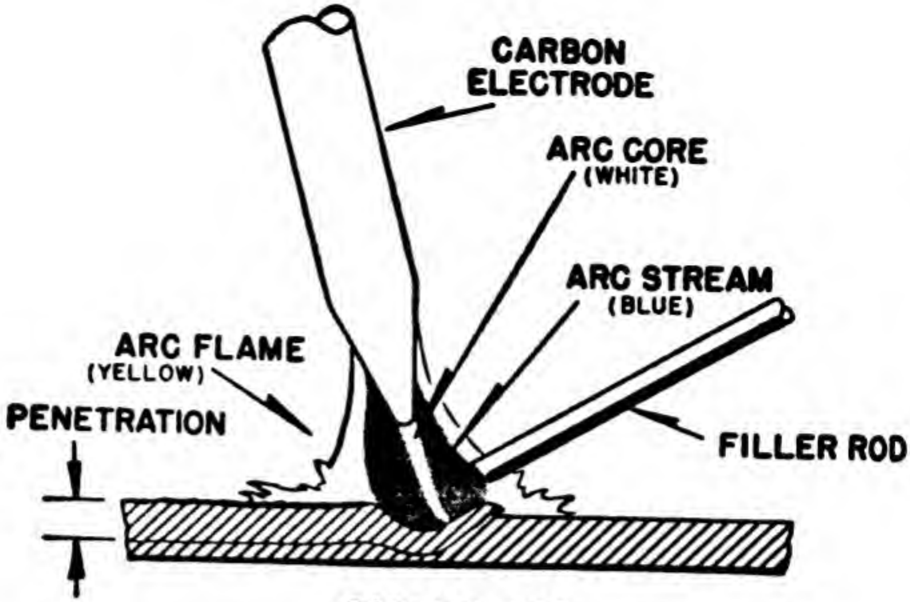


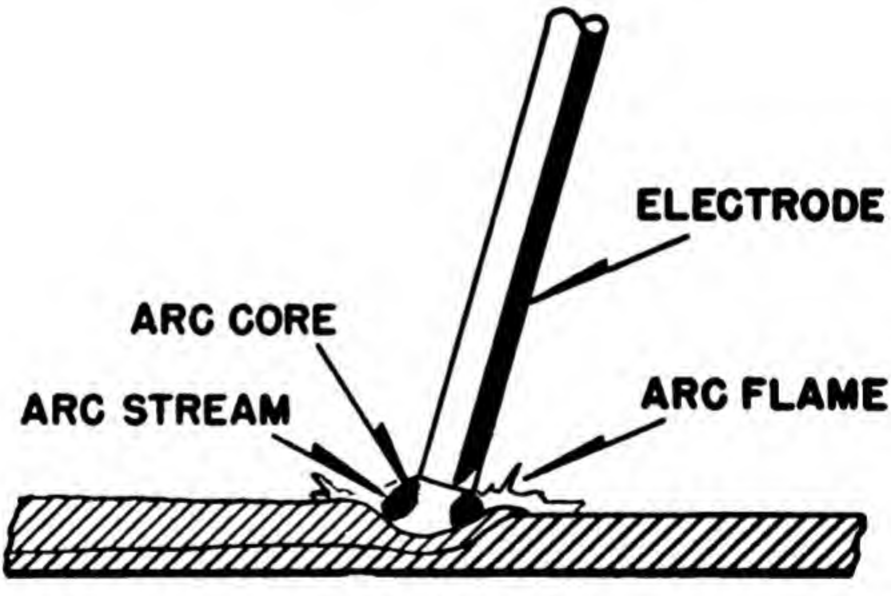
Figure 92.—Shielded metallic arc.

SPLICE WELDING OF TUBING

Figure 91 illustrates typical tubing repair jobs—an external sleeve splice and an internal sleeve splice.



CARBON ARC



Bare Metallic Arc

Figure 93.—Metallic arc and bare electrode.

ELECTRODES AND CURRENTS

Bare electrode.—A welding rod, without a special coating; when used, the arc is not shielded by a gas formation.

Shielded electrode.—Such rods have a special coating which forms a shield of gas around the arc.

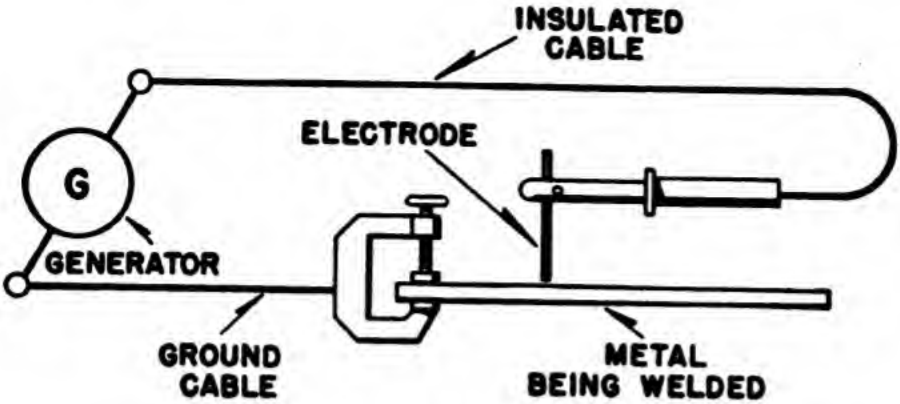


Figure 94.—Arc welding circuit.

POLARITY.—If the work is positive and the electrode negative, it is referred to as straight polarity.

ARC BLOW.—Arc blow (arc wanders), results from magnetic disturbances, which are prevalent around the area being welded. Elimination, in part, may be accomplished by rearrangement of ground cable or by changing the *pointing* direction of the electrode.

Chart 109.—Voltage and amperage for various electrodes

Diameter (inch)	Metal	Coating	Flat position		Vertical position		Overhead position	
			Volts	Amperes	Volts	Amperes	Volts	Amperes
3/32	Steel	Washed	17–20	75–85				
1/8	Steel	Washed	19–20	90–115				
3/16	Steel	Washed	20–25	135–150				
3/32	Steel	Shielded	20–22	60–75				
1/8	Steel	Shielded	25–26	90–120	25–27	65–75	22–24	75–80
5/32	Steel	Shielded	24–26	90–135	26–28	75–100	26–28	90–100
3/16	Steel	Shielded	24–30	100–175	28–30	100–130	30–35	100–125
3/32	Stainless steel	Shielded	25	60				
3/32	Inconel	Shielded	24	50				
1/4	Cast iron	Washed	20	150				

Chart 110.—Classes of electrodes

Class	Current	Position	Penetration	Minimum tensile strength lb. /sq. in.	Minimum yield strength lb./sq. in.	Use
A	Direct or alternating	All position	Shallow	62,000 as welded.	52,000 as welded.	To weld mild and alloy steel. For single bead.
B	Direct, reverse polarity.	All position	Deep	62,000 as welded.	52,000 as welded.	To weld mild and alloy steel. For heavy parts.
C	Direct or alternating	All position	Shallow	[1] 100,000	[1] 100,000	To weld alloy steel. (Heat treat after welding.)
D	Direct, reverse polarity.	All position	Deep	[1] 100,000	[1] 100,000	To weld alloy steel. For heavy parts. (Heat treat after welding.)

NOTE. [1]—Stress relieved—1,125° F.-1,175° F. for one hour.

Chart 111.—Specifications and classifications to which Lincoln electrodes conform

Electrode	A. W. S. classification	American bureau shipping	A. S. M. E.	U. S. Navy	Lloyds	U. S. Army #57-203-1B	U. S. Air Force #
Fleetweld 5	E-6010	Approved	U-68-69-70.	46E3 grade I class 1⅛, 5/32, 3/16 class 2¼, 7/32 class 3 5/16 (4).	Approved	Type I class WD-E6010	
Fleetweld 7	E-6012	Approved	U-69-70		Approved	Type I class WD-E6012	
Fleetweld 9	E-6030	Approved	U-68-69-70.	46E3 grade II, class 2¼, class 3 3/16, ¼, 5/16, (2) (4).	Approved	Type I class WD-E6020	
Fleetweld 10	E-6030	Approved	U-68-69 70.				
Fleetweld 11	E-6020	Approved		Being tested	Approved also fleet fillet.		

Fleetweld 11 HT.	E–7020	Approved	U–68–69–70.		Approved		
Fleetweld 35	E–6011	Approved	U–68, U–69, U–70.	46E3 grade III, class 1⅛, 5/32 class 2 3/16 (4)	Approved		
Fleetweld 37	E6013–	Approved	U–69, U–70	For under water welding per test EES–B7033–AP	Approved		
Fleetweld 47	E–6013	Approved	U–69–70		Approved		
Shield arc 85	E–7010	Approved	U–68–69–70	46E2 class 1⅛, 5/32 class 4 3/16 ¼ (2) (4)		Type II class WD–E7010	
Shield arc 100.	E–10010			46E3 grade EE ⅛, ¼ (4)			

Chart 111.—Specifications and classifications to which Lincoln electrodes conform—Continued

Electrode	A. W. S. classification	American bureau shipping	A. S. M. E.	U. S. Navy	Lloyds	U. S. Army #57-203-1B	U. S. Air Force #
Wearweld	----------	----------	----------	46E3 grade ED 1/8, 1/4 (4)	----------	----------	
Stainweld A-5.	----------	----------	----------	46E4 grade II class 1 3/32, 5/64 1/8, 5/32, 3/16 (2) (4)	----------	----------	Type I grade 3E (3).
Stainweld D	----------	----------	----------	46E4 grade IV class 1 3/32, 1/8 5/32, 3/16 class 2 1/4 (4)	----------	----------	
Aluminweld	----------	----------	----------	46E1 grade II class 2-32, 1/8 5/32, 3/16; class 3 1/4	----------	----------	

Aerisweld				Navy tests EES6374 D-3/16 B704B-1/8, 5/32 (4)			
Stable arc new cathode, swiftweld.	E-4511						Type I—grade 1E (3)
Planeweld 1 and 2.	E-10012 and E-6013			46E3 grade I class 1 1/16, 3/32 for PW-2 (4)			See p. 2.
Ferroweld							Type I—grade 4E (3)

Courtesy of the Lincoln Electric Co., Cleveland, Ohio.

Chart 112.—Trouble-shooting chart for arc-welding machines

Trouble	Probable cause	Remedy
Machine fails to hold the *heat* constantly.	Rough or dirty commutator	Commutator should be trued or cleaned.
	Brushes may be worn down to limit of adjustment or life.	Replace or readjust brushes.
	Brush springs may have lost adjustment or may be broken.	Replace or readjust brush springs.
	Field circuit may have variable resistance connection or intermittent open-circuit, due to loose connection or broken wire.	Check field current with ammeter to discover varying current. This applies to both main generator and exciter, if used.
	Electrode lead or work lead connections may be poor.	Tighten all connections.
	Wrong grade of brushes may have been installed on generator.	Check with manufacturer's recommendations.
	Field rheostat may be making poor contact and overheating.	Inspect rheostat and clean and adjust finger tension on switch.

	Brush-shifting or other mechanical current-adjusting mechanism may have loose or worn links.	Check current-adjusting mechanisms for back-lash and play.
	Current control brush holder contact springs may be worn out or bent. Contact surface may be dirty, rough or pitted.	Inspect, replace needed parts, clean internal contact surface of control device. Smooth up roughened surface.
	Current control brush holder support stud and mating contact surfaces may be dirty or pitted and burned.	Clean brush holder stud and internal contact surfaces—use light application of vaseline to stud and replace. If brush holder internal contact surface is burned, replace brush holder and support stud.
	Engine regulator shorting switch out of adjustment.	Adjust switch contacts or mercury switch tilt angle so circuit is open when engine is at full speed and when welding.
Welder starts but fails to generate current.	May be running the wrong way	Check direction of rotation with manufacturer's instructions or direction arrow. On three-phase motors, direction of rotation may be changed by interchanging any two input leads.
	Generator or exciter brushes may be loose or missing.	Be sure that all brushes bear on the commutator and have proper spring tension.

Chart 112.—Trouble-shooting chart for arc-welding machines—Continued

Trouble	Probable cause	Remedy
Welder starts but fails to generate current—Con.	Exciter may not be operating	Check exciter output voltage with voltmeter or lamp.
	Field circuit of generator or exciter may be open.	Check for open circuits in rheostat, field leads, field coils. Also check resistors and rectifiers, if any. Some machines give less output when fields are open.
	Generator may be reversed in polarity due to another machine or incorrect operation in parallel with another machine.	Flash the field with a storage battery or another generator, first with one polarity and then with another to see if it builds up. (Flash exciter field, if set, has separate exciter.)
	Series field and armature circuit may be open-circuited.	Check circuit with ringer or voltmeter.
	Reversing switch wiper contact is bent, not clearing the blade of switch when switch is closed.	This shorts the exciter series and causes failure to generate. Bend or replace to secure correct operation.
Welding arc is loud and spatters excessively.	Current setting may be too high	Check setting and current output with ammeter.

	Polarity may be wrong	Check polarity. Try reversing polarity or try an electrode of the opposite polarity.
	Engine regulator shorting switch closes intermittently, when running at full speed, causes increasing surge of current and spatter.	Adjust so contacts are well open or mercury level well below contact on mercury tilt switch when engine is at full speed position of engine regulator (bellows fully extended).
Welding current too great or too small compared to indication on the dial.	Current control, shaft and handle may have turned slightly in the insulation bushing of the current control brush holder, caused by turning the handle too hard against one of the stops.	See that current control indicator yellow arrow is in the horizontal position when handle is turned against stop in the minimum direction.
	Exciter output low causing low output compared to dial indication.	Field discharge resistor wired to reversing switch and open-circuited. Check for circuit through it.
	Current control set to minimum and welder output so great that motor stalls when arc is struck.	Motor is probably running backwards or series fields connected reversed to make a cumulative series generator. Check rotation.

Chart 112.—Trouble-shooting chart for arc-welding machines—Continued

Trouble	Probable cause	Remedy
Motor trips off the line	Power circuit may be single phased	Check for one blown fuse or dead line.
	Welder may be operating above current capacity.	Check load against welder name plate.
	Welding electrode or work leads may be too long or too small in cross-section.	Check terminal voltage while machine is loaded; it should not exceed 40 volts when operating at rated current.
	Surrounding atmospheric temperature may be too high.	Make sure that temperature in motor-generator room or housing does not exceed 100° F., and that there is no interference with normal ventilation of the machine.
	Motor input voltage too low (or too high) under load.	Motor supply voltages should not fall below 90 percent of normal voltage. Have power company check transformer and line capacity. If supply leads too long or too small, should be corrected.

Machine fails to start	Power circuit may be completely dead	Look for open disconnected switch, fuses removed from clips, or blown fuses.
	Power circuit may be single phased. Power-line voltage may not be suitable for motor, or may be extremely low; may be accompanied by chattering of the motor starter.	Look for one blown fuse or one dead line. Check voltage with voltmeter, particularly at the moment of attempted starting.
	Machine may be jammed	See that armature turns over easily by hand, and look for foreign material in air gaps.
	Motor starter may be single phased	Check to see that all figures on starter make contact when closed.
	Overload protecting device may be tripped or contacts open-circuited.	If machine has had time to cool after tripping due to over-load or is cold and starter fails to close—check for circuit through push button, N. V. R. coil and thermostats to find the open-circuited part. See wiring diagram for normally closed and open contacts on the push button.

CHAPTER 12

AIRCRAFT HYDRAULICS

PRINCIPLES

Hydraulics, as discussed in this chapter, may be defined as the study and application of fluids in motion and under pressure as applied to aircraft hydraulic systems. For all hydraulic specifications and references refer to MIL–H–5440.

DEFINITIONS.—Force is the action of one body upon another, or more simply, the push or pull of an object. Force is usually independent of area. A force of any intensity, however great or small, may be applied to an object of any size, however great or small. For every force applied there is an equal and opposite reaction.

Pressure is the *amount* of force applied over each unit of area. This tells us that when using pressure, the area to which it is applied must be known. The standard unit for expressing pressure in hydraulics is pounds per square inch (p. s. i.). The F. A. P. (Force-Area-Pressure) triangle is the easiest way to remember the formulas for solving pressure and force problems. (NOTE: Viscosity is a measure of the internal resistance of the fluid itself to flow.)

The V. A. D. (Volume-Area-Distance) triangle is a helpful aid to solving displacement problems.

FLUIDS

Of the different types of fluids used in the hydraulic systems of Naval aircraft, mineral base fluids are more widely used. Vegetable base fluids are still used in brake systems and struts of a few older types of planes. The latest thing in hydraulic fluids is the noninflammable type, known as Hydrolube "H-2", which is being specified for use in the production models of the latest aircraft designs and is being retroactively installed in the majority of existing Naval aircraft. The method of conversion to Hydrolube is described in Technical Order 13-51.

These fluids are not interchangeable; therefore, it is very important to check the name plates before filling hydraulic reservoirs, shock struts, and other units to determine which type of fluid is to be used.

Chart 113 makes a comparison of vegetable base and mineral base fluids.

Chart 113.—Vegetable and mineral base fluids

Characteristic	Vegetable	Mineral
Base	Castor oil, alcohol	Petroleum.
Color	Blue	Red.
Used in	Systems with natural rubber seals.	Systems with synthetic rubber seals.
Cleaning agent	Alcohol, lacquer thinner, toluene or vegetable base fluid.	Stoddard solvent.
Specification number	M-574	MIL-0-5606.
Odor	Castor oil	Engine oil.

Chart 114.—Composition of hydrolube "H-2"

Substance	Parts by weight
Ethylene glycol	57. 7±0. 5
Distilled water	42. 3±0. 5
Water soluble ploymer	11. 8±3. 0 (As required)

Inhibitors amounting to 3.8% of the finished fluid are added to the above substances.

SEALS AND PACKINGS

There are primarily four types of seals used in Naval aircraft hydraulic systems, namely: synthetic rubber, natural rubber, leather, and metal (crush washers). Since 1942, the material in AN standard packings has been synthetic rubber.

Figure 95.—Seals and packings.

Synthetic rubber seals are to be used with mineral base or Hydrolube fluids and natural rubber seals are to be used with vegetable base fluids. Leather or metallic seals may be used with any type of fluid.

The seals made of synthetic rubber, natural rubber and leather are of many types.

Hydraulic system components normally use AN standard seals and packings. Some components, however, incorporate nonstandard seals and packings. For replacement purposes, care should be exercised in the selection and installation of all seals and packings to assure that:

1. They are not overage (see Specification MIL-P-5516).
2. Their material is suitable for use in the fluid employed in the system. (Seals manufactured from overage or improper material may swell excessively or break-down prematurely and cause malfunction of the component with possible loss of hydraulic system pressure.)
3. They are of the proper size.
4. They are not damaged during assembly.

SERVICING

FLUSHING A HYDRAULIC SYSTEM.—It is possible that through error a vegetable base fluid may be put into a hydraulic system containing synthetic packings and designed for mineral-base fluid. This is undesirable for several reasons, the most important being that such fluids tend to swell the synthetic packings just as mineral-base fluids will cause natural rubber seals and packings to swell. This deterioration will result in the forming of a gummy residue which will impair operation of the system. Should the system work sluggishly, a test of the fluid should be made to determine whether the fluids have been inadvertently mixed. This test may also show the presence of considerable dirt in the system, which may cause leaks in the seals, or binding and wear of metallic parts and thus result in malfunctioning of the system. In either case the system must be flushed. The following general procedure may be followed to flush, fill and bleed the system if it becomes necessary to do so.

Fold the wings and secure with jury struts or cables. Hoist the plane and secure it so that the main landing gear and tail gear can be retracted and extended.

Drain the system completely. Open the lines at all actuating cylinders with the exception of the wing fold, in which case it is better to disconnect the lines or flex hose at the wing hinge swivel and drain each cylinder by pumping the piston rod back and forth. In some instances this will require disconnecting the piston rod end. In the case of the wing fold cylinder, disconnect the piston rod and do not reconnect it until later, as will be explained below. Disconnect the gun chargers and open the line at the wing hinge swivel, allowing the fluid to run out. Disconnect the pressure line at the main manifold and let it drain. Drain the reservoir completely by disconnecting the suction lines from both the engine-driven pump and the hand pump. Disconnect the line at the pumps, not at the reservoir.

Reconnect all the lines and fill the reservoir with a flushing fluid of naphtha or kerosene. Disconnect the return line at the reservoir and lead the line into an over-flow can. (In the case of a dirty system where the actuating cylinders are still in good shape, the two working lines may be connected together thus by-passing the actuating cylinders.)

Using the hand pump and opening each selector valve, operate each unit system in turn through at least five complete cycles.

Caution.—Be sure to maintain the reservoir fluid level by the addition of flushing fluid. All units must travel to full extent in both directions. Bleeding of the gun charging system will be explained later.

Open the wing fold selector valve. (Note that the wing piston rod has remained disconnected during this procedure and that operating the struts merely extends or retracts the piston rods in the actuating cylinders.)

Pull the engine through about 25 revolutions by hand to flush the engine pump lines. Drain the system as explained above.

Connect all lines except the return line to the reservoir, and fill the reservoir with the specified fluid. If a test stand

is available connect it to the test connections and proceed with filling.

Caution.—Be sure all lines are properly connected for normal operation of units. Be sure to make provisions for keeping the wings and the landing gear from falling before the actuating cylinders are full of fluid.

Operate the system until about 20 gallons of clean fluid have been run through the system.

Caution.—Keep the reservoir full at all times. The overflow fluid is not to be re-used.

TUBING AND HOSE

The two main types discussed herein are rigid tubing and flex hose. Dimensions of rigid tubing are stated in wall thickness and outside diameter as shown below.

Aluminum alloy (52SO) Federal Specification WW–T–787 is commonly used in hydraulic systems having a system pressure of 1,500 p. s. i. or less.

Stainless Steel (U. S. S. 18–8) Specification AN–T–43–2 and aluminum alloy (61ST) is used primarily in hydraulic systems having a working pressure in excess of 1,500 p. s. i., or where a line may be subject to heat or abrasion.

Caution.—In flushing or refilling a hydraulic system, great care must be exercised to assure that all air has been purged from the system. Air which is entrapped in the system will result in erratic operation of its components and may result in serious accidents.

FLEXIBLE HOSE

Flexible hose is measured according to the diameter in sixteenths of an inch. A dash number will be found on flexible hose which corresponds to the dash number of the rigid tubing with which it is to be used. Flexible hose line size is related to the outside diameter, also in sixteenths of an inch, of rigid tube with which it is used. For example: number 6 flexible hose is used with number 6 (⅜-inch) rigid tubing. However, the actual inside diameter of the flexible hose, according to type and size, is 1/16 to ⅛ of an inch less than

the outside diameter of the corresponding size of rigid tubing.

The information contained herein pertains to the application of various types of hose used in hydraulic systems of Naval aircraft. Aircraft hose shall be used only in the manner specified in pertinent directives to insure maximum service lift and safety of operation.

LOW-PRESSURE HOSE

IDENTIFICATION.—One broken yellow stripe running the length of the hose, coded to identify the manufacturer with the symbol, LP, and quarter of year and year of manufacture interspersed along the identification stripe.

APPLICATION.—This hose is used only with detachable end fittings in systems containing fuel, engine oil, hydraulic fluid, alcohol, water and air where the pressure does not exceed 300 p. s. i.

MEDIUM HIGH-PRESSURE HOSE

IDENTIFICATION.—Double broken yellow stripe coded to indicate manufacturer with the symbol, MHP, and the quarter of year and year of manufacture interspersed along the identification stripe. Class A hose is marked with 3,000 p. s. i. interspersed along the identification stripe in addition to the markings listed above.

APPLICATION.—This hose is used only with end fittings in hose assemblies. MIL–H–5511 hose is suitable for use with fuel, oil, coolant, alcohol, water, hydraulic fluid and air.

All medium high pressure hose assemblies are fire-resistant. This hose is recommended for all flexible connections forward of the firewall.

INSTALLATION.—In general, replacement of flexible hose shall be made with hose or hose assemblies of the same size, length and design as the original parts, unless otherwise indicated. Because of the various sizes, specification numbers, p. s. i. maximums, and the like, it will be necessary to refer to AND 10340 for additional information in order to select the correct hose for the intended application.

Install hose assemblies with sufficient length so that lon-

gitudinal stresses are not imposed. When pressurized, hose contracts in length and expands in diameter.

Install hose so that the identification stripe is straight after installation. Install hose with the same bend radius and supported in the same manner as the installation being replaced. Special instructions apply, however, if rerouting or other modifications are necessary.

HIGH-PRESSURE HOSE ASSEMBLIES (MIL-H-5512)

IDENTIFICATION.—Hose marked with single broken yellow stripes coded to indicate hose manufacturer with symbol, W, and the quarter of year and year of manufacture interspersed along the identification stripe. The hose assembly manufacturer's name or trademark is stamped on the end fittings.

APPLICATION.—High pressure hose assemblies, as shown on AN6292, shall be used only in aircraft hydraulic systems operating at 3,000 p. s. i.

INSTALLATION.—Install hose in a manner that will not impose longitudinal stresses. Install hose through openings in structures only when such openings are greater in diameter than the hose itself. Grommets shall be used wherever hose passes through a structure. Hose supports shall not restrict motion of hose or cause undue load which would tend to deform the hose.

HOSE CLAMPS.—Hose clamps should be tight but avoid overtightening. Approximately 25 inch-pounds torque in tightening the clamps is considered to be sufficient. Where torque wrenches are unavailable and in inaccessible spots, the clamps may be tightened finger tight plus one more complete turn to accomplish an approximately correct torque. Do not safety wire clamp adjusting screws. Deletion of safety wire will facilitate inspection and will permit retightening of the clamps as they become loose due to *cold flow* of the hose. However, do not repeatedly retighten clamps to the point where the hose is excessively distorted.

STORAGE AND HANDLING.—All of the hoses covered by this publication are manufactured from materials which are subject to deterioration by exposure to heat, excessive moisture,

and ozone. For this reason, storage shall be accomplished in cool dry places, away from electrical equipment. Preferably, hose should be stored in straight lengths to prevent permanent set in a curved position. Under ideal conditions, hose may be stored up to 2 years without adversely affecting performance. In instances where excessive heat, moisture

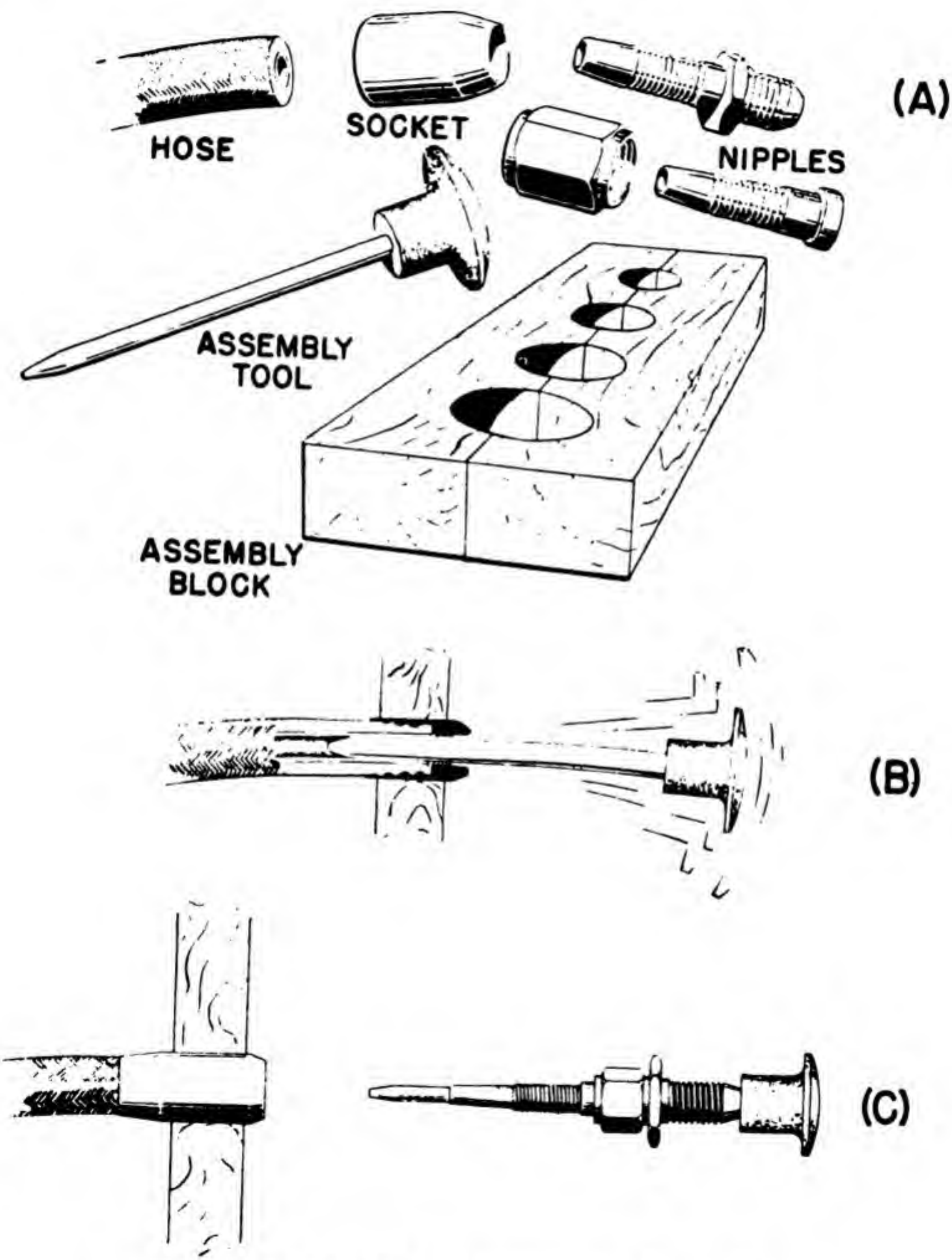


Figure 96.—Flexible hose equipment and assembly.

or ozone may have been encountered in storage, hose shall be tested in accordance with the procurement specification prior to use. Any evidence of cracking of the inner tube when a sample is slit and bent through 360° should be cause for scrapping the hose.

IDENTIFICATION.—ANA Bulletin No. 298 lists the coded dash markings assigned to various hose manufacturers.

RIGID TUBING

In effect, specification MIL-H-5440 states the following in regard to identification of system lines in the aircraft.

All lines shall be marked with their respective color bands, each band being ½-inch wide as shown in chart 115. In addition, all rigid tubing shall be identified by a number. This identification number shall be marked at both ends of the tubing in such a manner that it will be readily visible after installation and shall be of such a nature that it will not smear or rub off by contact incident to normal handling. A sufficient number of lines shall be marked in conspicuous locations throughout the airplane in order that each run of line may be traced. These markings shall be repeated as often as necessary, particularly on lines entering and emerging from closed compartments, to facilitate maintenance.

Chart 115.—Identification of tubing contents

System	Color
Air Pressure (compressed):	
Max. 25 p. s. i	Light blue-light green.
Min. 25 p. s. i	Yellow-light green.
Air ducts (cabin heaters):	
Cold	Yellow-red-yellow.
Hot	Light blue-red.
Anti-icing:	
Alcohol	White-yellow.
Glycerine and alcohol	White-red.
Carbon monoxide detector system	White-light green-red.
Coolant:	
Prestone	White-black-white.
Water	White.

Chart 115.—Identification of tubing contents—Continued

System	Color
Exhaust analyzer	Light blue-brown.
Exhaust lines from combustion-type Heater.	Brown-red.
Fire extinguisher	Brown.
Fire detector tubing	Brown-yellow.
Flotation equipment	Light blue.
Fuel:	
Gasoline	Red.
Propane	Red-light blue-red.
Gasoline supply lines to combustion type heaters.	Green-red-green.
Air vapor supply lines to combustion type cabin heaters.	Light green-red.
(a) Gasoline differential pressure.	Red-red.
(b) Oil differential pressure	Yellow-yellow.
Hydraulic pressure oil	Light blue-yellow-light blue.
Manifold pressure	White-light blue.
Manifold pressure line to fuel tank pressure unit.	Red-yellow.
Oil (lubricating)	Yellow.
(a) Oxygen:	
Distribution	Light green.
Filler	Light green-yellow-light green.
Pitot pressure: Airspeed	Black.
(b) Stall warning	Black-black.
Purging	Light blue-yellow.
Smoke screen equipment	Brown-white.
Static pressure:	
Airspeed, altimeter, rate of climb.	Black-light green.
Stall warning	Black-light green-black.
Steam	Light blue-black.
Vacuum	White-light green.
Vent (closed compartments, to permit air pressure equalization).	Red-black.
Water (drinking)	White-light blue-white.
Water (lavatory and waste)	Light blue-black-light blue.
Water injection system and water alcohol solutions.	Red-white-red.

In airplanes where there is an oxygen filler line from a filler valve to the oxygen cylinders and a distribution line from the oxygen cylinders to the dispensing equipment, the identification marking shall be as indicated. Where no filler and distribution systems exists, the oxygen lines shall be identified by light green.

The two black bands of the pitot pressure stall warning shall be spaced ⅛ inch apart.

Single color bands shall be ½-inch wide. Each color or multicolor bands shall be from ¼- to ½-inch wide. All bands shall completely encircle the tube.

One band shall be located on each tube segment, 24 inches or shorter, provided that both ends of the segment are within the same compartment. One band shall be located at each end of each tube segment longer than 24 inches. Where the tube segment passes through more than one compartment or bulkhead, additional bands shall be applied so that at least one band is visible in each compartment, or on each side of the bulkhead.

Pressure transmitter lines shall be identified by the same colors as the lines from which the pressure is being transmitted.

Filler lines (except as otherwise noted above), vent lines, and drain lines from functional or related equipment specified herein shall be identified by the same colors as the functional lines.

TUBE FLARING

TUBE FLARING PROCEDURE.—Tube flaring is a job requiring a great deal of precision. Poor flares are the cause of many system failures and should be checked against specifications. Application of the following suggested flaring procedure with a little practice should help to produce good flares.

Flare seats must be properly formed to the correct angle. Flares must not be cracked, nicked, or scratched. Flares must have proper outside diameter. (Use sleeve of triple-type or corresponding-type connector to gage the outside diameter of flare.)

Steps in tube flaring.—Cut tubing to correct length with fine tooth hacksaw or tube cutter. File square with a smooth file. Remove burrs from inside and outside with pocket knife or burr removing tool.

Caution—Clean tube thoroughly to remove filings and burrs. Place nut and sleeve on tubing. Flare tubing with clean flaring tool. Check flare for the following: Must have proper form. No cracks, nicks, or scratches. Outside diameter must check properly with the sleeve.

After the flare is completed, clean the tube again. This point cannot be overstressed.

(Note: Never file down an oversized flare or reflare one that is undersized, as all additional work tends to work harden the metal and it will not meet specifications.)

TUBE CONNECTIONS

There are two general types of AN tube connectors commonly used—the 3-piece and the 2-piece types shown in figure 97.

Assembly procedure for tube connectors.—Tubing should be brought up against the fitting snugly and square with the threads before starting to thread the nut. To assure that such a fit is made, all tube nuts shall be started by hand.

In the past, fittings have been manufactured conforming to three different specifications: NAF (no longer in use); AN (this type has been recently accepted as standard); and, AC (although being replaced, this type is still infrequently used). The distinguishing characteristics between AN and AC are shown in figure 98. In addition, the various fittings may be identified by the color code shown on the following page.

Tighten the fitting to the correct torque. In doing so, use one fitting wrench to hold the tube connection and one to apply the torque. Crescent wrenches, or other types which may damage the work, should not be used.

Caution.—Do not apply excessive torque, as this thins out the walls of the flare.

COLOR CODE

Type	Material	Color
AN	Aluminum alloy	Blue.
AN	Steel	Black.
AN	Bronze	Brass.
AN	Aluminum bronze (sleeve only).	Silver (cadmium plated).
AC	Aluminum alloy	Gray or yellow.
AC	Aluminum bronze (sleeve only).	Silver (cadmium plated).
AC	Steel	Silver (cadmium plated).

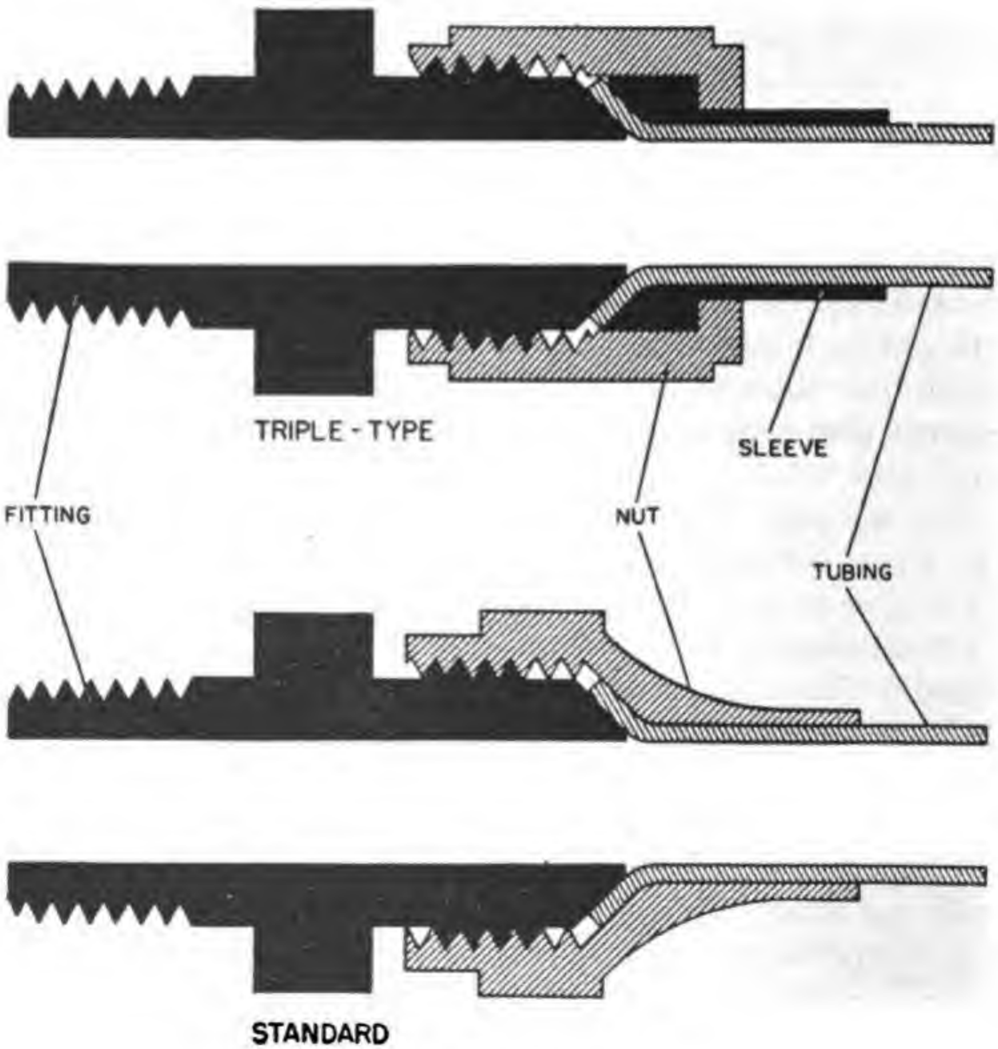


Figure 97.—Tube connectors.

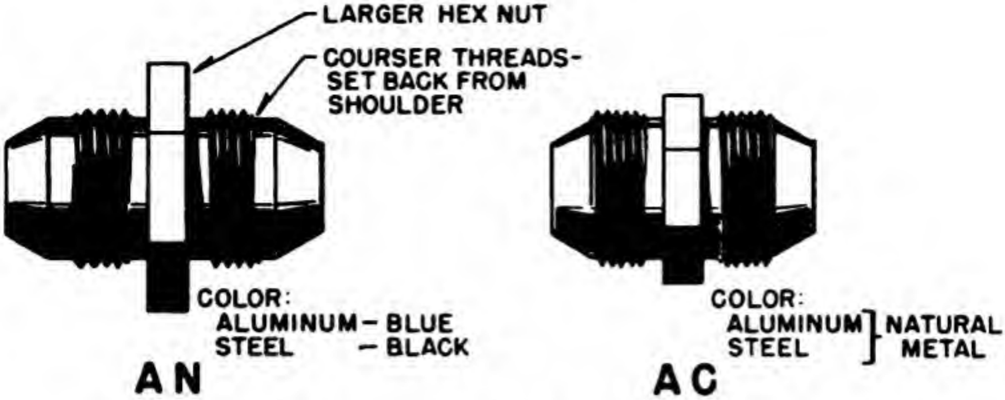


Figure 98.—Comparison of AN union to AC union.

Recommended torque values are shown in chart 116.

Chart 116.—Wrench torque for fitting nuts on various sizes of tubing

Tubing O. D. inches	Wrench torque for tightening AN-817 and AN-818 nut (pound-inch)			
	Aluminum alloy tubing flare AND10061 or AND10078		Steel tubing flare AND10061	
	Min.	*Max.*	*Min.*	*Max.*
1/8				
3/16			30	70
1/4	40	65	50	90
5/16	60	80	70	120
3/8	75	125	90	150
1/2	150	250	155	250
5/8	200	350	300	400
3/4	300	500	430	575
1	500	700	550	750
1 1/4	600	900		
1 1/2	600	900		
1 3/4				
2				

When connecting hoses to rigid lines, a bead is worked on the end of the tubing.

SOLDERED FITTINGS

Attaching soldered fittings.—Soldered fittings can be used only on copper. Since the annealing temperature of

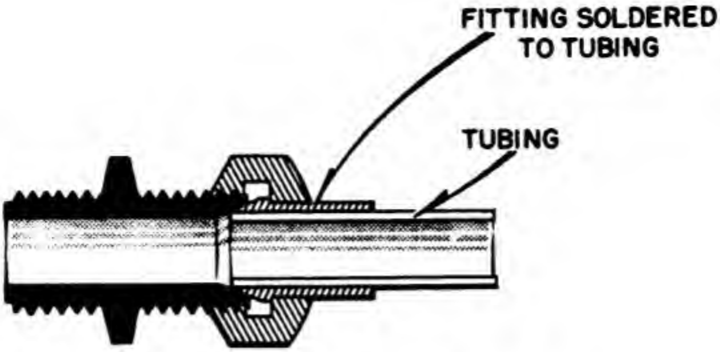


Figure 99.—Soldered fitting.

copper is higher than that of soft solder, the tubing should be silver soldered. The soldered fitting uses a union tail which is slipped on with the nut. The tail is soldered flush with the end of the tubing, after which the fitting is screwed together like any other type, as shown in figure 99.

TUBE FITTINGS

Threads used on practically all hydraulic system components and fittings are straight threads conforming to Specification MIL–S–7742 National Fine Series Class 3 (NF3). Figure 100 illustrates the types of AN fittings used in tubing work.

FITTING ASSEMBLIES.—All pipe threaded connections depend upon the close tolerance of their tapered threads for sealing against external leakage. Although in some cases antiseize compound is recommended on the lead threads of the male fittings, no gaskets are used to prevent leakage. However, straight threaded fittings (except when used as tube connections where the flare provides a positive seal) require either a metal crush washer or a rubber gasket to prevent external leakage. The choice of assemblies depends largely upon the design of the hole in the unit into which the fitting is to be screwed. If serrations are machined about the hole, an AN–901 crush washer is recommended. If, however, the hole is made with a recess or chamfer, a rubber gasket or an O ring seal should be used. Chart 117 is a self-explanatory fitting assembly chart.

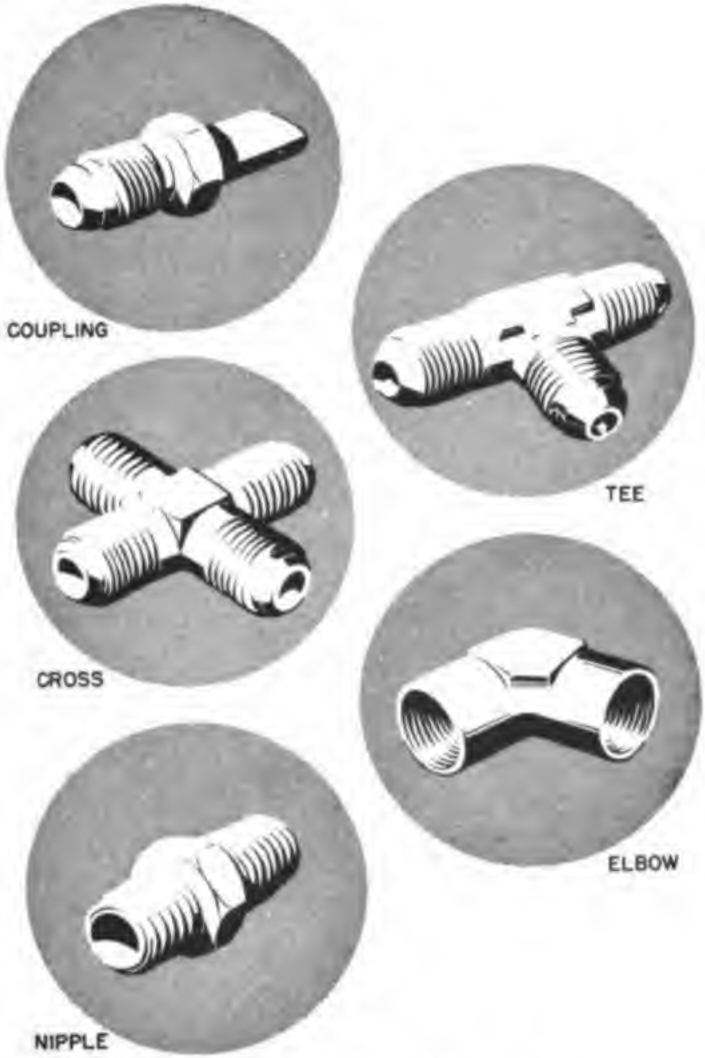


Figure 100.—AN fittings.

EXAMPLES OF FITTING ASSEMBLY MASTER CHART APPLICATION

An AN–815–8 fitting for a tube whose O. D. is ½ inch would screw into a ¾-inch screw threaded hole with 16 NF threads per inch. This fitting would employ a rubber gasket, an O ring seal, or a crush washer, depending upon the design of the unit.

A fitting for a tube whose O. D. is ½ inch would screw into a ⅜-inch pipe threaded hole with 18 NPT threads per inch. This fitting would employ antiseizure compound but no crush washer or rubber gasket.

Chart 117.—Fitting assembly master chart

Dash Nos.	Tube O. D.	Screw threads	Pipe threads	AN-901 AN-6290	All pipe fittings	AN-6227
2	⅛″	5/16″-24 NF	⅛″-27 NPT	2	1	5
3	3/16″	⅜″-24 NF	⅛″-27 NPT	3	1	6
4	¼″	7/16″-20 NF	⅛″-27 NPT	4	1	7
5	5/16″	½″-20 NF	⅛″-27 NPT	5	1	8
6	⅜″	9/16″-18 NF	¼″-18 NPT	6	2	9
8	½″	¾″-16 NF	⅜″-18 NPT	8	3	12
10	⅝″	⅞″-NF	½″-14 NPT	10	4	
12	¾″	1 1/16″-12 N	¾″-14 NPT	12	6	
16	1″	1 5/16″-12 N	1″-11½″ NPT	16	8	
20	1¼″	1⅝″-12 N	1¼″-11½ NPT	20	10	
24	1½″	1⅞″-12 N	1½″-11½ NPT	24		
28	1¾″	2½″-12 N	1½″-11½ NPT	28		
32	2″	2½″-12 N	2″-11½″ NPT	32		

NOTE.— When referring to AN-912, 919 or 893 reducer fittings, it is generally permissible to specify both thread sizes. For example: AN-919 ¾″-16 NF-5/16″-24 NF, or AN-919-8-2. A letter "D" following the dash number indicates that the fitting is aluminum alloy.

TUBE BENDING

Bending methods.—Smaller sizes of aircraft tubing may be bent by hand to larger radii; other sizes by hand tube bender, production tube bender, or by properly shaped bending blocks. Chart 118 indicates the processes by which different materials should be bent and the heat treatment required. Common fillers are sand, rosin and low melting point alloys, such as Cerro Bend, which melts at approximately 150° F. Fillers must be tightly packed into the tubing to support the tubing walls properly.

INSTALLATION OF TUBING

Figure 101 illustrates the correct methods for installation of rigid tubing.

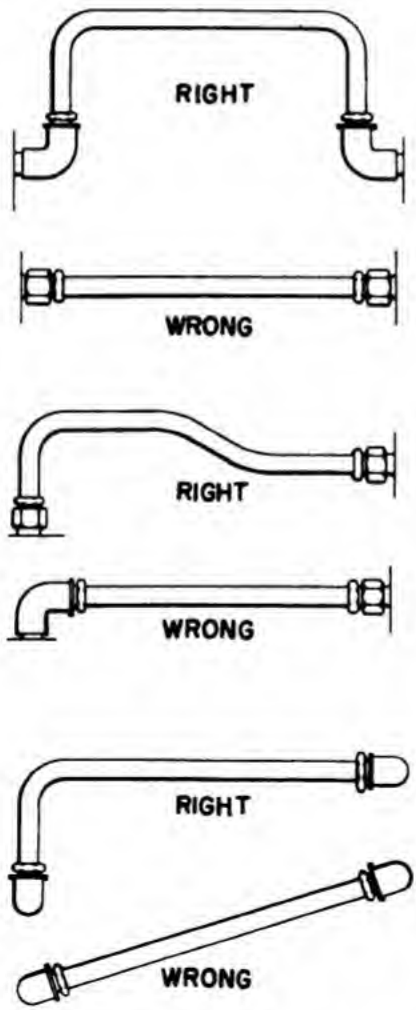


Figure 101.—Proper tube installation.

Chart 118.—Bending processes

Tube material	Outside diameter (inch)	Wall thickness (inch) incl.	Minimum bend radius: O. D. × factor below: Structural use	Minimum bend radius: O. D. × factor below: Piping fluids	Method of bending (See legend below.): No filling	Method of bending: Sand: Coarse	Method of bending: Sand: Fine	Method of bending: Rosin	Method of bending: Spec. 11078 or other low temp. fusing alloy	Heat treatment: Before bending	Heat treatment: After bending
Aluminum and 52 aluminum alloy.	0.25 1.50	0.032		3	#3		#1 or #2		#4 or #5 #1 or #2		
	1.625 3.000	.057		3	#3		#1 or #2				
17 and 24 aluminum alloys.	0.25 2.00	.022 .065	6	4	#3		#1 or #2		#4 or #5	Anneal or heat treat.	Heat treat.
	2.25 3.75	.065 .120	6	4			#1 or #2			Anneal or heat treat.	Heat treat.
Brass			5	4			#1 or #2	#1 or #2	#1 or #5		Anneal.

Copper	0.125 1.125	.035 .049	3	3	#3		#1 or #2	#1 or #2			Anneal.
Copper, silicon, bronze.			3	3	#3		#1 or #2				Anneal.
1025 steel	0.125 1.50	.028 .065	5	3	#5	#6				Torch	Normalize.
	1.625 4.000	.065	5	3	#5	#6				Torch	As required.
X-4130	0.188 1.500	.022 .065	5	3		#6				Torch	As required.
	1.625 2.750	.049 .120	5	3		#6				Torch	As required.
Corrosion resistant steel.	Minimum bend radius depends on composition, condition, and bending equipment.								#2		Anneal.

LEGEND METHODS OF BENDING

#1 Cold bending (hand).
#2 Cold bending with machine (using filler).
#3 Cold bending with machine (internal mandrel).
#4 Cold bending with die press (with or without filler).
#5 Cold bending with rolls (with or without filler).
#6 Hot bending (hand).

Chart 119 shows recommended minimum dimensions from end of tube to start of bend.

Chart 119.—Bend radii for conduit and fluid lines

Nominal tube O. D.	Minimum bend radii [1]		Steel tubing	
	2S-½H, 52SO	Corrosion-resistant [2]	Desirable radius	Minimum radius [3]
1/8	3/8			
3/16	7/16	21/32	3/4	3/8
1/4	9/16	7/8	1	3/8
5/16			1 1/4	3/8
3/8	15/16	1 5/16	1 1/2	3/8
1/2	1 1/4	1 3/4	2	1/2
5/8	1 1/2	2 3/16	2 1/2	5/8
3/4	1 3/4	2 5/8	3	3/4
7/8			3 1/2	7/8
1	3	3 1/2	4	1
1 1/8			4 1/2	1 1/4
1 1/4	3 3/4	4 3/8	5	1 1/2
1 3/8			5 1/2	1 3/4
1 1/2	5	5 1/4	6	2 1/8
1 5/8			6 1/2	2 1/2
1 3/4	7	6 1/8	7	2 7/8
1 7/8			7 1/2	3 1/4
2	8	7	8	3 5/8

[1] Increase bend radii when wall thickness is below standard. Bend radii measured to inside of bend.

[2] Equal to 3½ times tube diameter.

[3] The minimum radius will be used only when the desirable radius cannot be used.

Chart 120 shows spacing for hydraulic line supports as taken from applicable specifications for hydraulic systems.

HYDRAULIC SYSTEMS—TYPES

There are six types of aircraft hydraulic systems—four nonpressurized systems and two pressurized systems.

TYPE A—NONPRESSURIZED SYSTEMS.—

1. Open center—variable delivery pump control. System

under pressure only when one or more services are operated.

2. Open center—constant delivery pump, pressure relief valve control. System under pressure only when one or more services are operated.
3. Closed center—variable delivery pump control—automatic device (Navy), automatic or manual device (Air Force) for depressurizing. System depressurized only during in-flight operations when none of the services are being used.
4. Closed center—constant delivery pump, pressure regulator control—automatic device (Navy), automatic or manual device (Air Force) for depressurizing. System depressurized only during in-flight operations when none of the services are being used.

TYPE B—PRESSURIZED SYSTEMS.—

1. Closed center—variable delivery pump control.
2. Closed center—constant delivery pump, pressure regulator control.

Chart 120.—Hydraulic line support spacings

Nominal tube O. D. (inch)	Maximum length between support centers (Measured along tube)	
	Aluminum alloy (inch)	Steel (inch)
1/8	9½	11½
3/16	12	14
1/4	13½	16
5/16	15	18
3/8	16½	20
1/2	19	23
5/8	22	25½
3/4	24	27½
1	26½	30

Hydraulic systems are grouped in three classes:

1. 3,000 p. s. i. class, where the cut-out pressure at the main pressure controlling device is 3,000 p. s. i.

2. 1,500 p. s. i. class, where the cut-out pressure at tl main pressure controlling device is 1,500 p. s. i.
3. 1,000 p. s. i. class, where the cut-out pressures at t main pressure controlling device is 1,000 p. s. i.

Type A nonpressurized systems are so designed that wh the operation of a unit is completed during *in flight conditi* take-off and landing excluded, the entire system is return to the maximum allowable back pressure. These syste may remain under pressure while the airplane is on t ground to assure pressure for the landing gear down lin for power operated brake systems, and other necessary desired pressurized services. Provision shall also be made restore the brake system pressure automatically when landing gear is extended. Provisions for automatically manually restoring pressure in other parts of the syst immediately prior to or concurrent with the operation those parts of the system shall also be provided.

Type B pressurized hydraulic systems of the pressuri in flight type are so designed that when the operation o unit requiring low pressure has been completed, the syst will automatically return to operating pressure.

A study of the schematic diagram of the complete hydrau system will aid the Aviation Structural Mechanic in trou shooting. The schematic diagram will contain a co scheme to identify the high- and low-pressure lines, and a the following information:

1. Operating pressure of all systems and sub-systems
2. All relief valve cracking pressures. Initial air press of accumulators and their oil capacities.
3. Pressure range of the pressure regulator.
4. Diameter, wall thickness, and material of tubing.
5. Total and reserve capacities of reservoir or reservo and system.
6. Displacement of fluid in cubic inches of each actuati unit for both extension and retraction.
7. Actuating cyliner piston head diameter, rod diamet and travel of each unit.
8. Number of required revolutions of hydraulic motors f

each half cycle of operation and the torque load required for each unit.

9. Type of power-driven pump and displacement.
10. Indicated flow of fluid through all hydraulic units.
11. Reservoir pressurizing system source, operating pressure, and schematic diagram of plumbing.
12. Simple schematic line diagram of linkages showing mechanical disconnect, mechanical downlocks and uplocks, and other data to tie the mechanical system to the hydraulic system for analysis.
13. Manufacturer's name and part number of all units.

CHAPTER 13

NAVAL AVIATION PUBLICATIONS

AIRCRAFT BULLETINS AND SERVICE CHANGES

Bureau of aeronautics bulletin.—A bulletin issued by the Bureau of Aeronautics characterized by information (mandatory) required for safe aircraft operations. An example of such a bulletin might be an Engine Bulletin or bulletins concerned with flight safety.

Bureau of aeronautics aircraft service changes.—Changes from the Bureau, to be effected upon a plane, are referred to as Bureau of Aeronautics changes. Each plane model has its changes listed in sequence. The object of such changes is to bring about better performance.

BUREAU OF AERONAUTICS PUBLICATIONS

Buaer instructions or notices.—The Bureau of Aeronautics issues instructions or notices covering subjects with pertinent information related to policy and administration of Naval Aviation Activities.

Naval aeronautics publication index.—An index issued in June by the office of the Chief of Naval Operations and Bureau of Aeronautics with an annual supplement issued in December. The index covers publications from many different sources concerning Naval Aeronautics. However, it does not include specifications.

Technical notes.—Technical notes, numbered consecutively by the year, are not considered as mandatory. They are issued for all units of naval aviation for informational purposes. Technical notes still in effect and those that have been canceled can be determined from a listing compiled and published from time to time.

Technical orders.—Technical orders are mandatory orders or directives containing technical data for naval aviation commands directing the execution of certain action on aircraft or equipment under the cognizance of the Bureau of Aeronautics.

AN publications.—Such publications are prepared by the Bureau of Aeronautics in conjunction with the U. S. Air Force. AN specifications are issued and made available to both branches (USAF and Navy). Example of an AN publication is the General Manual for Structural Repair AN–01–1A–1.

Federal specifications.—A description of materials normally made available by Government purchases take the form of Federal Specifications. Federal Specification QQ–1–716, fully describes galvanized iron, available to Government agencies. It provides information covering the galvanic coatings and their recommended uses, sheet thickness, etc.

SERVICE UNIT REPORTS

Rudms.—RUDM stands for "report of unsatisfactory or defective material." Service units report *part* failure, if there is evidence of failure due to design and/or construction characteristics. Such reports may be accompanied by recommended changes.

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